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ABSTRACT

Presented is the final report of the Science Curriculum Improvement Study (SCIS). Included is the background and a brief history of the SCIS project, an outline of the project development processes, evaluation made of SCIS during development, a summary of financial support for the project, names of advisory and staff members, a historical chart of SCIS unit publications, a listing of dissertations relating to SCIS, a summary of annual sales, and a listing of SCIS resource centers. (SL)

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SCIS Final Report

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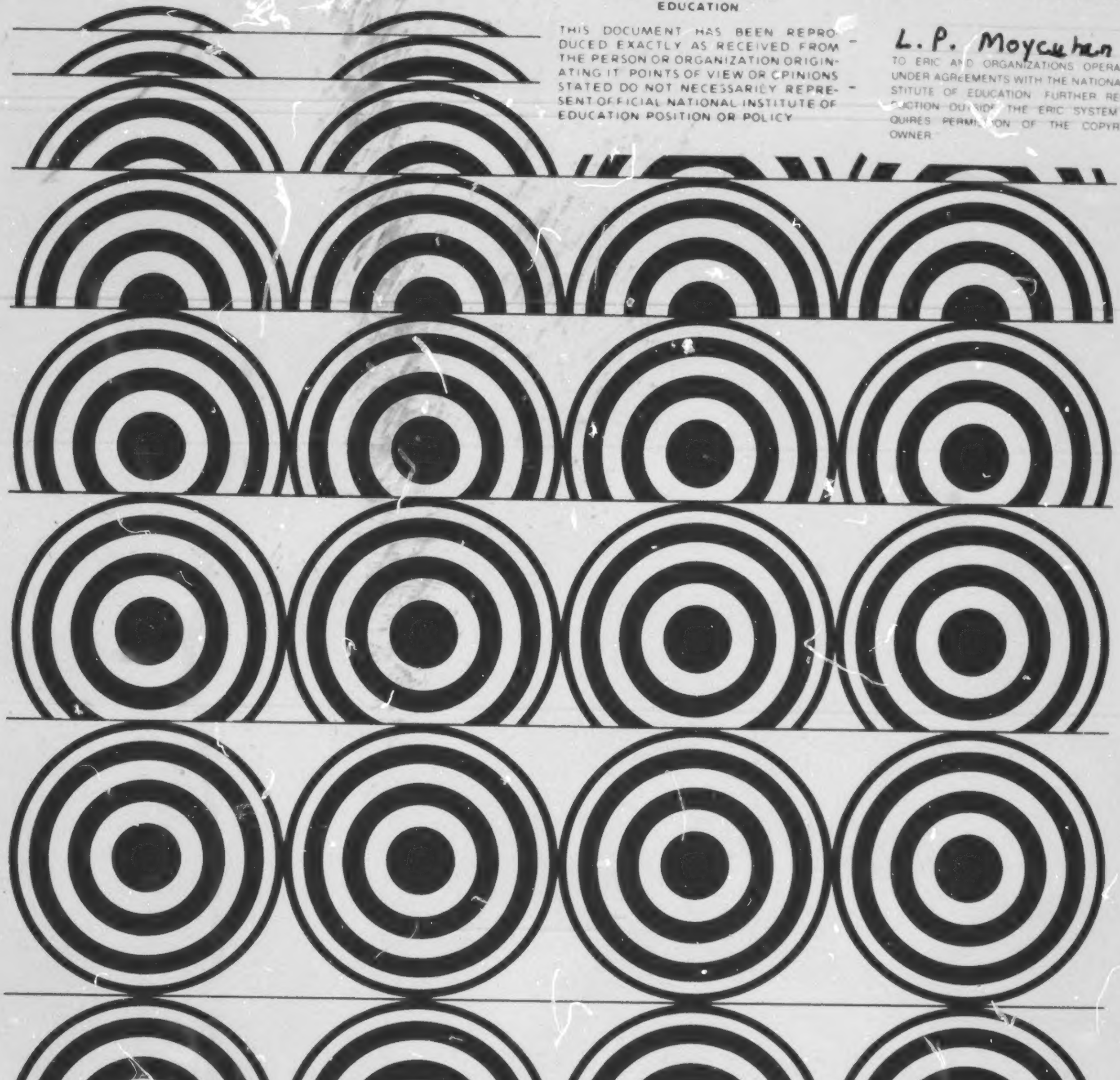

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University of California Berkeley, California 94720

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Final Report prepared by: James R. Eakin
Robert Karplus

Art Director: Tony Calica

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Preface

The Science Curriculum Improvement Study was a collaboration of scientists, educators, teachers, and others who worked together to advance the scientific literacy of elementary school children. With support from the National Science Foundation and the cooperation of students, teachers, and administrators, the SCIS project created a seven-year, articulated elementary science program in which children investigate phenomena in the physical and life sciences. The SCIS equipment kits, teacher's guides, and student manuals are the tangible products of this effort. Research studies, articles, and films have documented the development work and its products. In this *Final Report* we give an account of how the SCIS curriculum materials came to be. The fourteen years of the project were an exciting and very worthwhile time for us, and we were grateful for the opportunity to convert our ideas into reality.

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Chapter 1 Background

Have you ever sorted the books in your library according to their subject matter, only to find a few remaining that "didn't fit"? In a way, this problem is similar to problems that face a scientist. He/she makes observations on crystals or butterflies or comets and must face the fact that some observations may not fit the expectations. Such an experience can be unsettling, but it can also lead to new understanding and insight.

Creating in students the ability to cope with unexpected findings is an objective of the innovators who have been developing new educational programs during the last twenty years. After all, the replacement of persons by machines in industry and agriculture will soon lead to the mechanical performance of most routine and repetitive work. Human beings will then be free to pursue more stimulating work that requires imagination and adaptability.

The educational system must bear an additional burden in this situation. Not only traditions of knowledge and culture from prior generations, but also inquisitiveness and mental flexibility must be transmitted to students. Increased autonomy for students has, therefore, become an important educational trend in the last two decades. During the same period, scholars, educators, and teachers began to collaborate with one another and benefit from financial support made available by government agencies and private foundations.

Scientists, mathematicians, anthropologists, linguists, and other scholars first set to work on the development of new high school courses for the improved preparation of the increasing number of college applicants. At the same time, some scientists and educational leaders recognized that pre-high school curricula also presented opportunities for improvement that should not be missed.

To determine whether the National Science Foundation should provide financial aid for a concerted effort of curriculum improvement in elementary school science, the American Association for the Advancement of Science organized three regional conferences of scientists, teachers, school administrators, and psychologists during 1960-61. The conferences concluded that instruction in science should be a regular part of school offerings from kindergarten on. The participants, therefore, recommended that a major effort at improving course materials and teaching practice be undertaken.

The report prepared by the steering committee for the conferences contains a discussion of many concerns that were aired by the participants. Here we shall only list four points of general agreement:

1. *Science instruction at the elementary level should deal in an organized way with science as a whole.*
2. *There must be a clear progression in science from grade to grade.*
3. *There should be no single, national curriculum in science.*
4. *Science teaching should stress the spirit of discovery characteristic of science itself.*

("Science Teaching in Elementary and Junior High Schools." Science, CXXXIII, No. 3469 (June 23, 1961), pp. 2019-2024.)

After this encouraging report was released in the spring of 1961, several study groups were set up to formulate elementary science curricula. As we shall describe in more detail in Chapter 2, the decision that the Science Curriculum Improvement Study should become a major development project was made in the fall of 1963. The SCIS leadership concluded at that time that an additional alternative responding to the above four points would add significantly to the science teaching options open to local school districts.

This, then, was the immediate background that made the development of the SCIS program possible: interest by scientists who wished to contribute to education, financial support from the federal government in the post-Sputnik years, and a strong expression of need on the part of the schools and the science education community. In the following eight chapters and thirteen appendices of this Final Report, we have described the most important aspects of program development, preparation of a commercially-marketed edition, and dissemination.

A brief history of the SCIS project is provided in Chapter 2 to give the reader an overview of the happenings affecting the project between 1958 and 1975. The funds supporting this work, the annual expenditures in various significant categories, the members of the SCIS Advisory Committee, the staff members, and the publication dates of all units are detailed in Apendices A through E. In Chapter 3 we have briefly described each publication which is being distributed to the interested public. Appendix F lists all the earlier editions of these materials as well as the authors, while Appendix G lists films.

The development and conceptual focus of the physical and life science sequences are described in Chapters 4 and 5 by Robert Karplus and Chester A. Lawson, the persons with overall responsibility for directing this work. Chapter 6 rounds out the information about the teaching program itself with a summary of the classroom teaching approaches and three significant contributions to the theory of instruction.

The research and development process is taken up in Chapter 7. The various trials that played an important role in the evolution of each teaching unit are included in the table in Appendix E. Doctoral dissertations resulting from studies during this process are given in Appendix H. The formative evaluation procedures, objectives, and value system used during unit development are identified in Chapter 8, with formative evaluation reports listed in Appendix I. Also described in Chapter 8 are evaluation supplements for teachers of the final edition units.

Chapter 9 is concerned with dissemination and teacher education. Articles of general interest written in connection with the SCIS program are listed in Appendix J. Annual kit and replacement sales are given graphically in Appendix K. Finally, resource centers sponsored by the publisher for dissemination purposes are identified in Appendix L.

Chapter 2 A Brief History of the Project

The chain of events leading to the SCIS project began in June of 1958, when Robert Karplus, Professor of Physics at the University of California, Berkeley, attended a meeting of university and industrial research chemists and high school chemistry teachers who were gathered to discuss the needs for new curricula in high school chemistry. The principal outcome of this meeting was the founding of the CHEM Study project, which ultimately developed a new text, laboratory guide, and instructional films for use in high school chemistry courses. Karplus's thinking went in a different direction, toward improved science education during the elementary and junior high school years, before students enroll in specific discipline-oriented science courses in high school.

An influence that had prepared Karplus for an interest in elementary education was his participation in science sessions in his older children's elementary school classes in Orinda, a Berkeley/Oakland suburb. He found not only that the pupils were interested, but that other classes in the school and other schools in the community were eager to have him visit. His inquiries into the schools' regular science programs revealed that the science textbooks spent most of their time on the bookcase. Only a few teachers with special interest in the weather, rocks and minerals, birds, or plants had developed their own short courses in these areas and were presenting them to the children. Still, little exchange of materials took place among teachers, and they seemed to have little awareness that the conceptual framework and systematic process of inquiry of science might deserve regular treatment at the elementary school level. In fact, several of Karplus's university colleagues who had become involved in school science activities during these early post-Sputnik years cautioned strongly against science in the elementary school because of the children's immaturity and the teachers' unspecialized preparation.

In the summer of 1958 Karplus recruited several colleagues from the University of California who were also residents of Orinda. Together with the Orinda school administration, they framed a proposal under which the district would engage a number of science teaching specialists to develop curricular materials while teaching science classes in the Orinda schools. The university scientists were to outline the curriculum strategy and serve as expert consultants. This proposal was addressed to the National Science Foundation, whose research directorate was then supporting Karplus's studies with graduate students and post-doctoral assistants in quantum field physics. Though the Foundation rejected the proposal, conversations with Richard E. Paulson and Arthur Roe of NSF's education office encouraged Karplus to develop a new proposal to be submitted by the University of California. University faculty members Leo Brewer (Chemistry), Arthur Pardee (Biochemistry), Lloyd Scott (Education), and Karplus took primary responsibility for this project concerned with course-content improvement in elementary school science. In June, 1959 the proposal resulted in a small grant, the Foundation's first at the elementary school level. It led to Karplus's gradual further involvement in educational development and research.

In recounting the actual project activities during the subsequent eighteen years, it is worthwhile to identify six distinct phases, each about three years long. We shall now give a description of the work during each of these phases in chronological order. The appendices contain specific information concerning the grants, expenditures, personnel, and publications.

Exploration Phase, 1959-1963

During the first year of the project, which took the name Elementary School Science Project (ESSP), three science units were written--*Coordinates*, *Force*, *and What Am I?* (human physiology). They were prepared by the project leaders and staff and were used in several schools in the area at all grade levels. The teachers selected activities or provided emphasis as they thought appropriate. The units included simple laboratory investigations, with equipment made in the University's shops.

Frequent classroom visits by Karplus and the project staff members provided evidence of the children's interest in the programs. However, the visits also revealed great misunderstandings on the part of teachers and pupils with regard to the significance of force, graphical data representation, and similar matters. In the spring of 1960, therefore, Karplus began to teach the units himself on a regular twice-a-week schedule in his children's first, second, and fourth grade classes.

At the same time, Karplus contacted the Berkeley psychology department in the hopes of getting assistance with the interpretation of the children's reactions and the formulation of more successful approaches.

These inquiries resulted in several exchanges of ideas, the most important and extensive of which involved Theodore Kompanetz, a graduate student in psychology. Kompanetz attended Karplus's classes, reviewed the children's reactions and questions, suggested novel teaching approaches, and also took turns teaching to illustrate his ideas. He made frequent references to the work of Piaget as he identified the reasoning patterns the children were applying.

The result was that Karplus directed his attention toward finding relationships between modern science and the children's spontaneous conceptualizations. Since the other investigators in the ESSP did not share this interest, he established the new Science Curriculum Improvement Study.

To broaden his knowledge, Karplus read about past efforts in science education, such as those of Glenn Blough, J. Darrell Barnard, and Gerald Craig. He studied developmental psychology, educational handbooks, and other relevant publications. Especially influential were Karplus's 1961-62 part-time science teaching experience at the Berkwood School in Berkeley as well as the reading of Bruner's *The Process of Education*, Kuhn's *The Structure of Scientific Revolutions*, and the writings of Piaget. Karplus also participated in the first summer writing conference sponsored by the Elementary Science Study during 1962, and in two planning conferences sponsored by the American Association for the Advancement of Science.

In 1962-63 Karplus served as Visiting Professor of Physics at the University of Maryland, where he continued his educational investigations. He was joined by Herbert D. Thier of the Falls Church, Virginia Public Schools and Doris Hadary of American University. The 1963 summer writing conference of MINNEMAST (Minnesota Mathematics and Science Teaching Project), in which Karplus and Thier participated, allowed them to consolidate their ideas. At the end of 1963, the conceptual structure (see Chapter 4) and educational philosophy (see Chapter 6) of the Science Curriculum Improvement Study program had been outlined in very general terms. There remained the detailed and demanding tasks of (1) refining this outline in the light of classroom experience and (2) producing curriculum materials that would enable many elementary school teachers to implement the curriculum in their classrooms.

Berkeley Area Trials, 1963-1966

In the fall of 1963 the project returned to Berkeley, where it proposed to the National Science Foundation "to continue a small-scale project to explore a novel approach to the selection, organization, and presentation of subject matter in elementary school science." The National Science Foundation reviewers of the proposal urged reorientation of the effort from a mere study toward the development of course materials that could be used in schools. The funds subsequently granted and the annual expenditures are summarized in Appendices A and B.

Herbert D. Thier joined the Study as assistant director at this time. He took responsibility for establishing laboratory schools in which children and teachers would use SCIS materials consistently over a period of years, so that an articulated program would be developed.

During this year, Karplus and Thier authored four science units in trial editions, and these were used in the primary grades of the cooperating schools--Washington, LeConte, and Berkwood in Berkeley, and Glorietta in Orinda. James R. Eakin served as technician for gathering, assembling, and distributing the vital laboratory materials.

Three prominent educators, A. W. Foshay of Teachers College, Columbia, John I. Goodlad of UCLA, and Sister Jacqueline Grennan of Webster College, formed an advisory committee of educational consultants that was joined by scientific consultants Howard Bern of the University of California, Berkeley and Laurence Strong of Earlham College during the next year. Other prominent scientists and educators served on this committee later (see Appendix C). Besides helping the staff evaluate the educational value of the new teaching materials, these advisors urged the project to focus on the problems of nationwide trial and dissemination. They agreed to sponsor trial centers at their institutions for testing a revised, commercially published edition of the SCIS materials beginning in 1966.

Through the SCIS Newsletter and presentations at professional meetings, two science educators learned of the SCIS program and moved quickly to introduce the units on an experimental basis in their communities. The two were John W. Renner at the University of Oklahoma in Norman and Richard Konicek, science consultant in Greenwich, Connecticut. They devised the necessary laboratory materials from sketchy information in the published teacher's guides, using their own ingenuity to make some of the items, and adding other materials supplied by parents. Their very favorable reaction was a strong stimulus that encouraged the wider distribution and trial of a revised edition by the project.

A first-grader discusses plants with SCIS Assistant Director Herbert D. Thier.

In 1964 and 1965 the project staff (Appendix D) gradually expanded, with the addition of elementary and secondary school teachers, a psychologist, an editor, technicians, and artist-designers. Additional units were issued in trial editions (see Appendix E). Individual activity sequences involving plants or animals were being designed, but these did not form a life science sequence with a conceptual structure that paralleled the physical science sequence being developed by Karplus and Thier.

A temporary staff expansion during the summers brought to the group additional scientists and teachers with new ideas. One of these scientists was Chester A. Lawson, professor of Natural Science at Michigan State University, whose basic interests in biology had broadened to include human learning. He found that he could apply his scientific knowledge and pedagogical experience to the problems of elementary education and, therefore, joined SCIS full-time as director of life science. The program he developed with his associates is described in Chapter 5.

During this phase of its existence, the Science Curriculum Improvement Study evolved from a small exploratory activity to a major curriculum development project with potentially worldwide impact. A ten-year plan submitted to the National Science Foundation forecast total expenditures of more than $5,000,000 for the development and field test of a comprehensive elementary school science program. This was to be published first in a preliminary edition with limited commercial distribution, then in a revised final edition.

Selection of D. C. Heath and Company of Boston, Massachusetts, as publisher of the preliminary edition took place in June of 1965, after nine months of discussions with interested companies and the screening of publication proposals. Since no apparatus supplier was willing at that time to take responsibility for the entire equipment development and manufacturing effort, the SCIS project proceeded on a unit-by-unit basis, selecting a supplier for one unit at a time.

Five SCIS trial centers were established during 1965 and 1966, as follows:

New York (Teachers College, Columbia University) - Mary Budd Rowe, Coordinator
Los Angeles (University of California, Los Angeles) - Stanford M. Davis, Coordinator
Norman ((University of Oklahoma) - John W. Renner, Coordinator
Honolulu (University of Hawaii) - Albert B. Carr, Coordinator
East Lansing (Michigan State University) - Glenn D. Berkheimer, Coordinator

Preliminary Edition, 1966-1969

During this period the SCIS project engaged in two parallel tasks: the preparation, dissemination, and evaluation of the preliminary edition, and the invention, design, and trial of upper elementary grade units. Accordingly, the project staff again grew somewhat larger and now engaged in uniformly intense year-round activity, without additional working groups during the summer.

In the preparation of the preliminary edition, the authors at the SCIS project had to become accustomed to a new mode of operation as they worked with editorial supervisor Harley Mutzfeld, editor Pat Roennau, and designer Lucy Floyd of D. C. Heath and Company. Design of equipment kits was accomplished through collaboration with John Landvater and Joseph Gavin of Ohaus Scale Corporation, Elbert Little and James Dawson of Macalaster Scientific Corporation, and Armand La Selva and Gilbert Davidson of American Science and Engineering, Inc.

The joint efforts with the four firms were highly educational for the staff members involved, who recognized that the project was dependent on American industry for large scale manufacture and marketing. The lead-times involved in getting

Second-graders studying *Interaction and Systems* watch Staff Teacher Charlyn R. Sheehan explaining electric circuit puzzles.

ready for production and the cost-price relationship of the finished products were two important matters that had to be kept in mind. Besides making the materials available on a limited scale, work on the preliminary edition therefore prepared the project staff for the process of selecting a publisher and a manufacturer for the final edition.

The five trial centers for field testing the preliminary edition included rural, small town, suburban, and inner city schools. The five center coordinators and the cooperating schools performed an exceedingly valuable service for SCIS during the next six years by carefully evaluating the units in the preliminary edition as we shall describe more extensively in Chapter 7. Their overwhelming enthusiasm for the program in spite of minor deficiencies provided very important encouragement for the project staff in Berkeley.

Teacher education materials (*SCIS Sourcebook*, classroom films, phonograph records) for the trial centers were developed under the leadership of Willard Jacobson of Teachers College, Columbia. They enabled the trial center teachers to become familiar with the SCIS program and also facilitated the use of the SCIS materials in many other communities. An implementation program was set up at Berkeley under the direction of Jack Fishleder to inform interested science educators about the SCIS materials, the needs for teacher education, and promising implementation strategies. The activities of this program are described in more detail in Chapter 9.

The completion of the upper-grade units took place concurrently with the publication of the preliminary edition, as we stated earlier. Details of the investigations are described in Chapters 4 and 5. A factor that compelled some retrenchment in the project's activities was the federal budget ceiling imposed on all government expenditures during fiscal years 1968 and 1969. Funds that had already been granted were set aside for later use. Three specific consequences were (1) the postponement of completion of a science program for kindergarten (resumed in 1972--see below), (2) the elimination of a search for greater breadth in the upper-grade physical science units, and (3) the cancellation of a more systematically organized formative evaluation of the SCIS units that would lead to publishable results.

Final Edition, 1969-1972

The public's very positive response to the preliminary edition of the SCIS program threatened to exhaust the limited authorized printing before the final edition was scheduled for publication. Discussions with D. C. Heath in 1967 and 1968 in an effort to meet market needs terminated when the publisher, under new management, decided to end its association with the SCIS project after publication of only six units. Based on the evaluation already performed, the project planned to forego completing the preliminary edition after bringing out two units on which preparation had already begun. Instead, it was decided to concentrate on the final edition for all units. Rand McNally and Company was chosen as publisher in early 1969, and American Science and Engineering, Inc. (AS&E), one of the suppliers for the preliminary edition, was selected as final edition supplier after a thorough search among educational firms.

Editorial supervisor William B. Miller, Jr., editor Ruth L. Henoch, and SCIS project director Paul D. Lindquist were the principal Rand McNally staff members who worked closely with the SCIS authors on the final edition. James Miller, and later Joseph Walker, served as SCIS managers for AS&E. The very tight publication schedule put severe demands on the authors, who were greatly helped by the project's senior editor Diane N. Bramwell, equipment designer Marshall A. Montgomery, and coordinator George P. Moynihan. At times there were six units in various stages of production, so that successful management of all the manuscript corrections, equipment specifications, and illustrations became very important.

Thanks to an outstanding effort by all concerned, the twelve units of the final edition were published before the end of 1972. The trial centers contributed now by allowing a small field test of the upper-grade units in their trial editions, since preliminary editions of these units were never published. In this way, all the units benefited from use and evaluation in several widely differing communities before the final editions were prepared.

Expanded dissemination of the program resulted from the improved design of the materials and the more aggressive marketing by the new publisher. Here also the trial centers contributed by functioning as nuclei of regional efforts.

Kindergarten, Teacher Education, and Evaluation Materials, 1972-1974

After completion of the final edition, the project could take stock of the tasks that still remained and the funds that were available because of the budget deferrals in 1968 and 1969. Market surveys carried out by the publisher led to the identification of needs perceived by users and potential users of the program. Accordingly, the suspended kindergarten program was taken up again. It was released as *Beginnings* in a final edition after field testing in the Berkeley area and other communities where the SCIS program was being used.

The teacher education materials were reviewed with the help of comments from trial center coordinators and other science educators who had used them for inservice and preservice courses. The primary shortcoming of earlier materials, that they dealt only with the units in the preliminary edition, was overcome by the new *SCIS Teacher's Handbook* and a set of color films showing the use of final edition SCIS activities in many classrooms.

The need for an evaluation program geared to the SCIS units had been expressed by many school administrators who were considering the adoption of the SCIS program. They felt that evaluation activities scattered throughout the teacher's guides were not adequate. After research and design by evaluation specialist Rita W. Peterson, a set of twelve evaluation supplements was prepared, field tested, and made available for distribution to interested school districts. One important characteristic of these materials is that children are asked to make certain interpretations or predictions and then must provide a justification for their ideas; both the answer and its justification permit an evaluation of a student's understanding. More details are given in Chapters 3 and 8.

Public Information and Service, 1974-1977

With the completion of all planned project publications at the end of 1974, there remained only the need to prepare this final report and to continue to provide information concerning SCIS to interested individuals. Some materials, such as the *SCIS Teacher's Handbook*, *Omnibus*, evaluation supplements, and teacher education films are being distributed by the project's very small part-time staff as a service to the public.

In addition, the project monitors the production and distribution of the materials to assure the necessary quality control and service. As a matter of fact, both the publisher and the equipment supplier have improved their capabilities gradually as they became better acquainted with the product, the needs of the schools, and methods for dealing with misunderstandings and errors. Further, some need for materials development continues. The recent rapid price changes have led to the disappearance of a few items, such as paper trays and certain plastic containers from the market, so that it became necessary to find and test adequate replacements.

Public Domain Period, 1978-

At the beginning of 1978, the copyright on the SCIS materials held by The Regents of the University of California will pass into the public domain. Rand McNally's exclusive license for marketing the materials will expire at that time. All persons will then be able to use the work, without charge, in the English language, provided that written notice of such use is made to the University and provided that a publication incorporating written materials contains a statement that the publication is not endorsed by the Regents. It is the intention of the publisher to assure the continued availability of the current SCIS materials until their use has fallen to such a low level that maintaining an inventory of all the items is no longer practical.

Chapter 3 The Product

During the eleven years from 1963 to 1974, while the Science Curriculum Improvement Study was developing teaching materials for elementary school science, a total of fifty-one different teacher's guides was published by the project, D. C. Heath and Company, or Rand McNally and Company. Many of these were trial or preliminary editions that were superseded by revised versions. An overview of the publication program is presented in Appendix E and the authors are identified in Appendix F. The following are the teaching materials that represent the last and definitive stage of the development process.

The Teaching Units

We shall first briefly describe the thirteen basic units, published by Rand McNally and Company. They are introduced by *Beginnings;* the remaining twelve fall into a physical science sequence and a life science sequence, as illustrated in Figure 1.

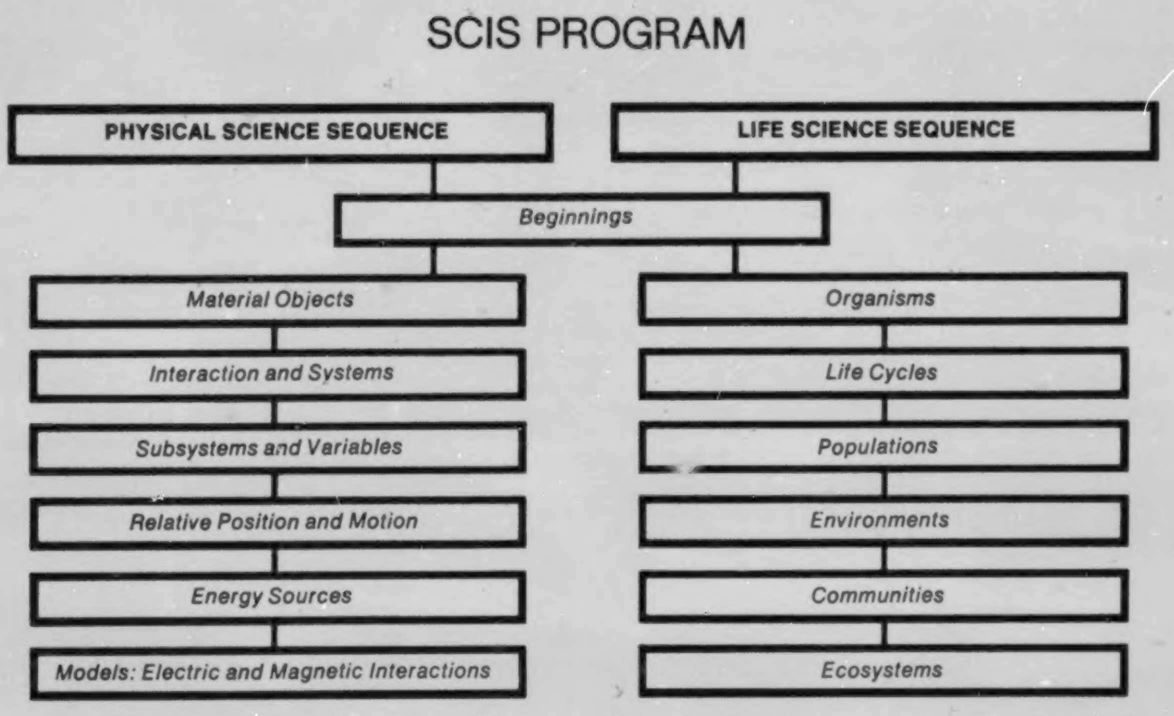
SCIS PROGRAM
PHYSICAL SCIENCE SEQUENCE
LIFE SCIENCE SEQUENCE
Beginnings
Material Objects
Interaction and Systems
Subsystems and Variables
Relative Position and Motion
Energy Sources
Models: Electric and Magnetic Interactions
Organisms
Life Cycles
Populations
Environments
Communities
Ecosystems

FIGURE 1. SCIS PROGRAM OVERVIEW

Beginnings (Kindergarten - 1974): This unit offers a wide variety of activities and experiences in both physical and life science. The program aims to develop the children's powers of observation, discrimination, and description. The children work with many different organisms and objects in the classroom and outdoors, playing games, solving puzzles, and comparing objects by their color, shape, size, texture, odor, and sound. The activities, which also introduce the children to ideas of number, volume, and change through time, can be taught in almost any order according to the interests and capabilities of the class.

Material Objects (1970) and Organisms (1970) - Level One: The two first-year units have certain common objectives that extend the kindergarten program--to sharpen children's powers of observation, discrimination, and accurate description. These objectives are attained as children observe and care for aquatic plants and animals, raise seedlings, and investigate the properties of a broad range of nonliving solid specimens (metal, wood, plastic, sand, ice, rocks, shells, sugar), liquids (water, liquid laundry starch, oil), and gases (air, Freon). The two units complement each other and can be taught in either order or concurrently.

Interaction and Systems (1970) and Life Cycles (1970) - Level Two: In both of the second year units the theme is change, observed either as evidence of interaction or by the development of a plant or animal. Both units require children to add the mental process of interpreting evidence to the observational skills they developed in the first year. In their laboratory work children use magnets, batteries, wires, bulbs, various chemicals, photographic and ozalid papers, pulleys, electric motors, seeds, mealworms, frog eggs, and fruit flies.

Subsystems and Variables (1970) and Populations (1972) - Level Three: The children observe and experiment with increasingly complex phenomena as they build on the first two years of the program and advance toward an understanding of the energy, matter, and ecosystems concepts. In the physical science unit they experiment with solutions, melting ice, evaporating and liquefying Freon, and the rotating Whirly Bird systems. In the life science unit the children observe two communities: grass, clover, crickets, and chameleons in a terrarium; and algae, *Daphnia*, snails, and damsel fly larvae in an aquarium.

Relative Position and Motion (1972) and Environments (1970) - Level Four: In the life science unit children consider for the first time some of the physical factors that shape an organism's environment. The children build terraria at the beginning of the unit, but redesign them to provide more favorable environments after experimenting with the living conditions of isopods, mealworms, beetles, clover, grass, and beans. The physical science unit presents activities concerning the spatial relationship of the children and their environment, and the spatial relationships of stationary and moving objects to one another. The introduction of reference objects, polar coordinates, and rectangular coordinates makes this possible.

Energy Sources (1971) and Communities (1971) - Level Five: In these units consideration of energy transfer between physical systems and of food transfer between plants and animals gives the children new insights into the relationships of objects and organisms surrounding them. The pupils apply the systems concept, identify variables, and interpret data regarding changes in motion or temperature as evidence of energy transfer. They observe various plants, crickets, and frogs, which form a community of organisms when taken together with decomposers such as molds, yeasts, and bacteria. Some of the organisms form a food pyramid.

Models: Electric and Magnetic Interactions (1971) and Ecosystems (1971) - Level Six: Both a climax and a new beginning occur in the last year of the SCIS program. The physical and life science concepts studied previously are integrated in the *Ecosystems* unit, when the children investigate exchanges of matter and energy between organisms and environment. The concept of a scientific model is introduced in the physical science unit, where the pupils relate matter and energy to electrical and magnetic phenomena. Thus they acquire a concrete basis for a later understanding of the electrical nature of matter.

The Evaluation Supplements

Next we will enumerate the twelve evaluation supplements published by the project. One is associated with each of the units except *Beginnings*. Under each title we have listed the names of the evaluation activities; those in the left column refer to attitudes and perception of classroom environment, while those in the right column refer to concept/process objectives. More information concerning the supplements is included at the end of Chapter 8.

Material Objects Evaluation Supplement (July, 1973)

- Attitudes in Science
- Our Science Class
- Faces

- Sorting Objects by Properties
- Grouping Pictures of Objects
- Sorting Objects by Material
- Serial Ordering
- Predicting and Experimenting

Organisms Evaluation Supplement (June, 1972)

- Attitudes in Science
- Our Science Class
- Faces

- Identifying Requirements for Plant Growth
- Describing Events in Aquaria
- Identifying Organisms and Habitats
- Diagramming Food Webs
- Discussing Experiments

Interaction and Systems Evaluation Supplement (November, 1973)

- Attitudes in Science
- Our Science Class
- Faces

- Identifying Interacting Objects
- Keeping Track of a System
- Identifying Systems of Interacting Objects
- Describing Evidence of Interaction
- Identifying Interaction-at-a-Distance
- Writing Experiment Reports

Life Cycles Evaluation Supplement (October, 1972)

- Attitudes in Science
- Our Science Class
- Faces

- Describing Plant Growth and Development
- Describing Animal Growth and Development
- Recognizing Stages in Life Cycle
- Inferring the Meaning of Biotic Potential
- Categorizing Organisms

Subsystems and Variables Evaluation Supplement (August, 1973)

- Attitudes in Science
- Our Science Class
- Faces

- Keeping Track of a System
- Identifying Subsystems
- Separating Mixtures
- Identifying Solutions
- Constructing and Interpreting Histograms
- Identifying Variables

Populations Evaluation Supplement (July, 1973)

- Attitudes in Science
- Our Science Class
- Faces

- Causes of Population Change
- The Population Concept
- Feeding Relationships
- Discussing Experiments
- The Community Concept

Relative Position and Motion Evaluation Supplement (November, 1975)

Attitudes in Science
Science Report Card
Letter

Mr. O Reports
Relative Motion
Sphere Tracks
Polar Coordinates
Rectangular Coordinates

Environments Evaluation Supplement (November, 1975)

Attitudes in Science
Science Report Card
Letter

Environmental Factors
Seasonal Changes
Interpreting Data
Trees

Energy Sources Evaluation Supplement (August, 1975)

Attitudes in Science
Science Report Card
Letter

Identifying Variables
Energy Chains
Predicting Temperature
Comparing Energy Transfer
Ice Melting

Communities Evaluation Supplement (November, 1975)

Attitudes in Science
Science Report Card
Letter

Cotyledons and Photosynthesis
Relative Population Sizes
Plants in a Food Web
Decomposers

Models: Electric and Magnetic Interactions Evaluation Supplement (November, 1974)

Attitudes in Science
Science Report Card
Letter

Electric Circuits
Models
Magnetic Field
Electricity Model

Ecosystems Evaluation Supplement (October, 1974)

Attitudes in Science
Science Report Card
Letter

Classroom Environment
Evaporation and Condensation of Water
Water Cycle
Oxygen-Carbon Dioxide Cycle
Pollution

The SCIS Teacher's Handbook

To assist in the orientation and education of teachers using the SCIS program, the *SCIS Teacher's Handbook* was published by the project in 1974. The *Handbook* is used as a reference during inservice and preservice courses. It is also intended to help teachers while they are teaching the SCIS program.

Background information included in the *Handbook* deals with the program's educational, psychological, and scientific foundations, approaches to teaching, and relationship to Piaget's theory. Program information covers each of the thirteen units, the evaluation supplements, laboratory materials, organisms, a concept encyclopedia, and a comprehensive glossary of terms. Supplementing these items are a teacher self-inventory, a reading list, and a description of the SCIS teacher education films.

The Teacher Education Films

From the beginning of teacher education in the trial centers, it was clear that films showing the SCIS program in action would be very helpful instructional tools. Accordingly, several black and white films were made and used successfully. With the revision of the program for the final edition, updated films were needed, and six color films (16mm, sound) were produced by the project. All films are listed in Appendix G.

How Can We Find Out? (1968). *Organisms:* This film follows first-grade children through discussion, formulation of hypotheses, and the planning of an experiment to determine the nature of the "black stuff" in an aquarium.

Don't Tell Me, I'll Find Out (1969), representative activities from *Organisms*, *Life Cycles*, and *Populations*.

Organisms: First-grade children observe aquaria, watch fish eat *Daphnia*, determine the source of "black stuff" on the bottom of the aquaria, and discuss a previous experiment in seed-planting.

Life Cycles: Second-grade students plant bean seeds in cups, observe fruit flies in the pupae and adult stages, and examine grown bean plants for new seeds. One child uses a biotic potential chart to explain what he understands.

Populations: Third-grade children observe terraria and see crickets eating clover and chameleons eating crickets. The teacher introduces the terms predator and prey.

What Would Happen If...? (1972), representative activities from *Material Objects*, *Interaction and Systems*, and *Subsystems and Variables*.

Material Objects: First-grade children sort materials and sand wood to compare wood and sawdust.

Interaction and Systems: Second-grade children experiment with various objects, and a teacher introduces the term interaction. Children experiment with aluminum and copper chloride and discuss the nature of a system.

Subsystems and Variables: Third graders experiment to find which part of a mixture changes the color of a BTB/vinegar solution. They also investigate variables of the whirly bird system.

Around the Corner (1972). Second-grade pupils go to a park area near their school to look for organisms and their habitats. A sixth-grade class searches for organisms and environmental influences around the block outside an inner-city school.

Energy and Models (1972), representative activities from *Energy Sources* and *Models: Electric and Magnetic Interactions*.

Energy Sources: Fifth-grade children explore rotoplane systems. A teacher uses a propeller and a paper airplane to invent the concepts of energy source, energy receiver, and energy transfer. The sequence concludes with an example of a discovery lesson--an exuberant ice-melting race.

Models: Sixth-grade children build energy sources for electric circuits and test materials to find those that will complete a circuit. The models concept is introduced when children are asked to determine the position, size, and shape of objects concealed in black boxes. The film ends with a friendly disagreement between a boy and girl who have developed differing models for the flow of electricity in a circuit.

Let's Try It (1973), representative activities from *Communities* and *Ecosystems*.

Communities: Fifth-grade children observe crickets in their terraria and set up experiments to find out what the crickets eat. Later, children observe frogs eat some of their crickets. In another classroom children place their dead crickets in wet sand and the crickets decompose, leading to the introduction of the concept of a community.

Ecosystems: Sixth-grade children are seen evaporating and condensing Freon in plastic bags. They recognize that this cycle is similar to water evaporating and later falling as rain. Another group of children is shown experimenting with BTB (an indicator for presence or absence of carbon dioxide) to determine what gases are taken in and given off by plants and animals.

Chapter 4 The SCIS Physical Science Program

by Robert Karplus

Imagine a theoretical physicist preoccupied with quantum field theory planning to teach in a third grade class! How do you suppose he would begin? In 1959 I faced this question while conferring with my oldest daughter's teacher. I selected graphing on a rectangular grid as a topic that was important in science studies and also allowed for many activities that might be interesting, entertaining, and achievable by children.

At the time, I had just learned that a small grant to support course content improvement in elementary school science had been awarded by the National Science Foundation to my colleagues and me at the University of California. I was eager to get some experience working with pupils to learn about their attitudes, interests, and abilities. I did not think about comprehensive conceptual schemes but only about getting started. After a brief exploration of the children's responses to locating points on a grid for the purpose of constructing pictures, I prepared the *Coordinates* teaching unit that began with these activities. It also included a second part on using peg boards and large-scale graph paper for displaying linear functions and other relationships.

Soon a second teaching unit entitled *Force* followed the first one. *Force* allowed the children to construct a rubber band scale that they calibrated with washers. The idea of force was then introduced in connection with a child pushing on the desk or pulling a wagon. The idea was later applied to the changes in motion that result when a force acts on an object--when hands deflect a tennis ball, or a rubber stopper is twirled at the end of a string.

Conceptual Problems

Observations in the classrooms where the two units were used soon convinced me that I had begun with a wrong approach. True, there were many children who enjoyed constructing the pictures on graph paper, assembling the scale, and many other activities. Most of the teachers also welcomed the format of activities in which their pupils were encouraged to follow up their own ideas. Even now, after more than fifteen years, some of the young adults who were students in those classes remember their experience with pleasure.

At the same time, many conceptual difficulties existed, but the teachers and children did not notice them. Thus, everyone recognized that the force of friction could slow down an object and gravity could speed it up, but no one appreciated the fact that friction between the tires and road could speed up a car or that gravity would slow down a ball thrown up into the air. The "balanced" forces on a body at equilibrium were mixed up with the "equal and opposite" forces in Newton's third law. The reaction forces exerted by rigid bodies were mysterious--how can the desk or floor exert a force?

Further exploratory work suggested that the children misunderstood two crucial ideas. First, the children identified the application of a force with the activity of their muscles. From the common sense point of view this is quite reasonable; scientifically, however, it is incorrect. The force exerted by the hand on the desk, for instance, must be grasped in terms of only these two objects--hand and desk--that affect each other. When force is associated with a single object (the muscle) rather than with the interaction of two objects, the force concept loses its scientific meaning.

The second difficulty arose from the concept of motion. Most persons are accustomed to thinking of motion as an activity--locomotion--and perceive it in relation to the immediate surroundings of the moving object. Can a box move? Most children will say no, not by itself. They do not separate the motion from whatever muscular movement or motor causes the motion. Yet in the scientific framework, motion is merely a change of location relative to a reference object, a purely descriptive concept.

The Interaction Concept

The experiences described above convinced me that the conceptual structure of science is different from the conceptual structure of common sense derived from everyday experience. From my discussions with Theodore Kompanetz in 1960, I concluded that I would have to think about physical concepts in a quite untraditional way if I were going to be successful in linking them to the children's existing concepts.

Most promising in this connection appeared to be the interaction concept, which embraces the action of forces, the exchange of energy, chemical effects, and the relation of living organisms to their environment. When objects do something to each other, they interact. In spite of the concept's simplicity, I had become accustomed to it through my work in quantum field theory. Here I had investigated cause-and-effect relationships whose space-time properties, including the creation and annihilation of particles, transcended Newtonian mechanics.

Along with interaction, the "cause" of natural phenomena, I was concerned with the phenomena themselves, with the objects and systems of related objects the scientist observes. Whatever group of objects interests the scientist, that group is designated as the system for investigation. In some way the objects in the system form a related whole--perhaps because they serve a function when taken together, like the parts of a clock, or because they interact with one another, as do the planets and sun in the solar system.

During the 1961-62 school year, I had the opportunity to teach regularly in a third grade class at the Berkwood School, a small Berkeley private school whose director, Betty Halpern, showed a friendly interest in my studies. I was able to introduce the ideas of system and interaction, relative position and motion using the artificial observer Mr. O, energy, equilibrium, interaction-at-a-distance, and chemical change. Not all children participated with equal interest in all activities, yet many seemed to understand at least some of the ideas. After a discussion of equilibrium as the state of a system when it is no longer changing, one child asked, "When a person is dead, is that equilibrium?" while another commented, "I know something that will never come to equilibrium: you--you will go on talking forever!"

The First Conceptual Outline

Encouraged by the experience, I included the chart in Figure 1 to illustrate the conceptual structure of science in the proposal I submitted to the National Science Foundation for continued support during the winter of 1962. Part of the explanation accompanying the chart elaborated on the relationships:

> *. . . [The scientist] calls what interests him his system . . . He can compare properties of the system at various times. He can determine in*

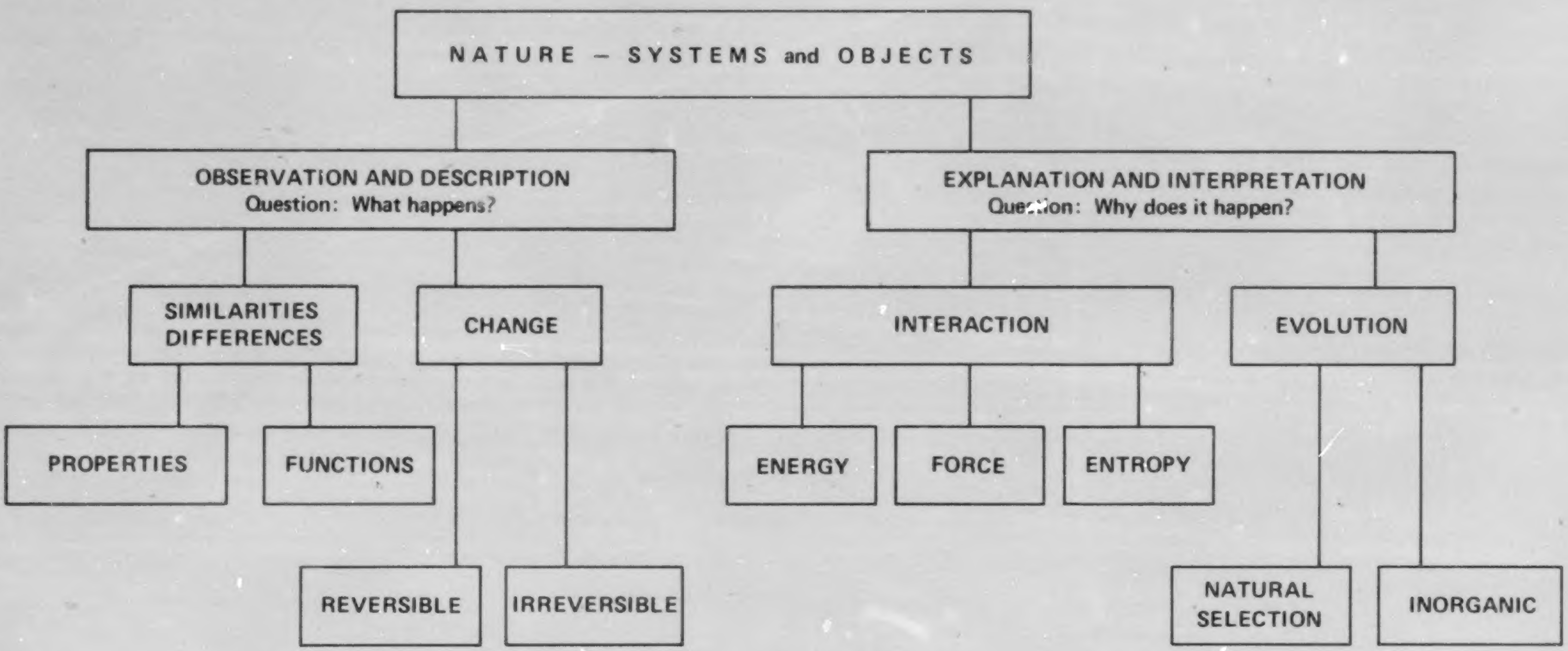
NATURE – SYSTEMS and OBJECTS
OBSERVATION AND DESCRIPTION
Question: What happens?
EXPLANATION AND INTERPRETATION
Question: Why does it happen?
SIMILARITIES DIFFERENCES
CHANGE
INTERACTION
EVOLUTION
PROPERTIES
FUNCTIONS
ENERGY
FORCE
ENTROPY
REVERSIBLE
IRREVERSIBLE
NATURAL SELECTION
INORGANIC

FIGURE 1. SCIS CONCEPTUAL OVERVIEW CHART, 1962

> *what ways the system has remained the same and in what ways the system has changed . . .*
>
> *A scientist may also wish to choose many systems and compare their properties at a given time. He then determines in what respects the systems are alike and in what respects they are different . . . The studies of similarities and differences can lead to schemes of classification . . .*
>
> *So far we have been concerned with making comparisons and describing the observations. Once this is accomplished, one may wish to determine why the observed changes take place and why the observed similarities and differences exist. To answer the former question, one turns to the interactions that occur among the objects that make up the system, or the interactions between the system and its environment. To answer the question about the variety in the possible systems of interest, one may turn to the evolutionary processes that have culminated in the present . . .*

Two other factors had to be considered before this approach could lead to a curriculum: the pupils' ability to make abstract distinctions and the pupils' preexisting concepts developed from their everyday experience. Sometimes these preconceptions give a child the sense of "I know what's happening here" and prevent him from observing the experiment critically.

During the next year, I was able to test these ideas with the help of Herbert D. Thier, Cynthia Ann Powell, and James R. Eakin in several elementary schools near Washington, D.C. Thier took special responsibility for teaching about objects in first grade classes, while I led the work on the interaction concept at the second grade level. Doris Hadary, professor of Chemistry at American University and consultant to the project, proposed using the term evidence of interaction to link the observable changes with the interpretations.

In the summer of 1963, Thier, Eakin, and I joined with the MINNEMAST project at the University of Minnesota to refine our ideas further. It was there that Jack Fishleder wrote the first draft teacher's guide entitled *Interaction and Systems* on which the fall 1963, trial edition of the same title was based. This unit's role was to introduce the concepts on the right, interpretive side of Figure 1.

Later in that academic year three more trial editions were published, all concerned with the left, descriptive side of Figure 1. One was *Material Objects*, which involved the observation and qualitative description of similarities and differences in properties of objects. The second, *Variation and Measurement*, was aimed at a quantitative description of similarities and differences with respect to length, area, and other easily measurable properties.

The third unit, *Relativity of Position and Motion*, concerned similarities and differences in the position and motion of objects relative to an external reference object. The last was particularly important for ultimately relating the ideas of interaction and systems to energy of motion, symmetry of systems, and changes in motion brought about by the action of forces. In the middle of 1964, therefore, the introduction to the physical science sequence in the early grades was well established along the lines of the conceptual structure in Figure 1.

Further Investigations

While trial teaching of the new first and second level units of the SCIS program was taking place, my colleagues and I turned to the basic exploratory work of extending the sequence in the direction of energy, reversibility, force, and other concepts listed on the last line of Figure 1. At the same time, we sought to give the children frequent opportunities for applying the interaction concept and finding evidence of interaction.

Two particular themes greatly appealed to us. One of these concerned the structure of matter: fluidity, dissolving, freezing, and other bulk properties of matter can be understood best in terms of a particle theory, according to which each substance is made up of many similar interacting particles. The second theme concerned the properties of a system associated with its state, properties such as energy or entropy that change when the state of the system changes. Related to these were (1) the concept of an equilibrium state, (2) the properties of a system that are conserved when a change in state occurs, and (3) the reversibility or irreversibility of changes in the state of a system.

Between 1964 and 1969 the SCIS physical science staff worked on the development of activities that would allow the filling out of these two conceptual themes during the upper elementary school years.

Since complete understanding of them clearly requires reasoning patterns on Piaget's level of formal thought, we expected to make only partial progress. Our central task, therefore, was to find activities that were interesting for children and could lead to helpful concept formation through the use of primarily concrete operational reasoning patterns. At the same time, we had to provide for a wide variety of investigations, since we soon found that the children's persistence in dissolving crystals, measuring temperature changes, timing the oscillations of a pendulum, or pursuing another specific line of inquiry was not nearly as extensive as ours.

The trial edition teaching units produced during those five years (see also Appendixes E and F) concentrated on certain areas such as *Solutions*, *Temperature*, *Phases of Matter*, *Energy*, and *Periodic Motion*. Two films, *Children at Play* (time reversed scenes) and *State of a System*, were included in the trials, though never as part of a published unit.

Third-graders using the final edition of *Subsystems and Variables* show SCIS Director Robert Karplus how to operate a whirly bird.

The use of the units and films in Berkeley area classrooms gave us valuable information regarding the children's preconceptions, the teachers' problems, the types of equipment that were serviceable, and the time required by the children for following a line of investigations.

Here are some excerpts from observer reports that illustrate our findings. In an activity of the *Temperature* unit (1965 trial edition), for instance, the children were concerned with the question of whether or not a thermometer was functioning properly. Each child had a thermometer and was challenged to do any experiment she or he wanted to do, keeping in mind this question written on the chalkboard: "Does the thermometer really work?"

> *Many of the children did any experiment at all that they could think of with the available equipment; only a few seemed to have some purpose for a given experiment in mind. This did not seem to me to be especially undesirable, however, since a number of children discovered very interesting things about the way thermometers behave. One child believed that "barricules" of red liquid go up when they're hot so when the thermometer is upside down the column of red liquid should go up (and get shorter). After doing the experiment and being surprised at the outcome he commented: "It's like it knew I was playing a trick on it." He did many more related experiments afterwards and was surprised at their results, but seemed to become convinced that he must have been wrong. Another child was dumbfounded by the fact that the liquid in an inverted broken thermometer tube does not fall out and thought that maybe it's the outside air's pressure that keeps it in. A few children seemed to be doing experiments related to the question on the blackboard, e.g., comparing the readings on two or more thermometers when they are placed into cold water and then into hot water.*
>
> *The discussion of results at the end of the lesson was not extremely enlightening. For the most part the children merely told about the temperature readings they had obtained in their various experiments. It was useful, perhaps, in pointing out to some of the children that they had not kept the question "Does your thermometer really work?" in mind.*

During a *Phases of Matter* activity that required testing the chemical reactions between drops of solutions of various inorganic salts, the observer found the following:

> *Children start working with the solutions, page 17 (C). Most children used "squirtfuls" rather than drops and mixed several solutions at a time. There was little evidence of systematic procedure with interactions between pairs of solutions.*
>
> *Discussion: Some children reported their specific observations. Teacher question, "If you mixed sodium iodide with lead nitrate, would you always get yellow?"*
>
> *Disagreement--some children said yes, some said no. Some did not think they would get the same results "tomorrow."*

During other activities of the same unit, these behaviors were observed:

> *One boy became interested in the colored cobalt chloride solution. He did an experiment to see if he could filter out the color from the solution.*
>
> *The children made rapid and apparently accurate use of the spring scales. They read tenths of grams easily and positively. As the children worked, the observer asked some of them to predict the weight of the ice-cube-and-bag system after the ice melted. Some felt it would be heavier, "because water's heavier than ice." Others believed it would be lighter "because water's lighter than ice." One boy thought it might be "just about the same" because "it's still going to be the same material."*

The next account describes a discussion between children and a project staff member during the early planning of activities relating to a particle model for matter:

> *Teacher opened discussion with a reference to the scientific models they had discussed briefly in the previous lesson. He asked them, "What is a model?" to which they replied, "airplane, tanks, figure robot."*
>
> *Then he suggested that they think of a model in a different way.*

T: When we want to know something about something we can't see, we think about it in our mind; we imagine what it must be like to have these properties. What would be a model for air?

C: clear plastic - see through it
water - walk through it
see through it

C: Can't breathe water.

T: Another model for air might be a sponge. It stretches, you can push it and pull it.

C: No, you can't see air.
It doesn't have a color.
You can't walk through it (sponge).
Air isn't square.
Air doesn't have holes in it.

T: (Introduces particle model.) Another model might be like tiny particles so small they can't be seen. They must be moving; they're hitting each other, and outside they are hitting the trees.
And there's a lot of holes in air.
(Draws on the chalkboard - balloon)
We can't see them even with the most powerful microscope.

C: Do they sleep?
Are they sort of like an animal?

T: No, we don't think they are alive.

In *Periodic Motion*, the requirements for the children to measure time and observe motion accurately were quite demanding. Here is the account of one class session in which the pupils worked with a spring oscillator to which magnets were attached as weights.

> *Teacher: "Make sure you stretch the spring the same distance each time. The only variable we are changing is the number of magnets."*
>
> *Some kids use the ruler when they stretch the spring, some don't. With only two magnets on the spring, the kids have trouble counting the number of cycles, partly because the system oscillates rapidly, and partly because the bounce converts to sideways swings. With three or more magnets there is no problem.*
>
> *About half way through the hour, a youngster says, "The more weight, the less bounce." With this clue, others begin to appreciate the relationship between weight and period. Some repeat their earlier observations when they see one X on the graph not following the pattern of the other data points.*

The hour-glass egg timers used during *Periodic Motion* were themselves objects of considerable interest, as shown by the following report:

> *At the end of class four boys collected seven timers. They lined them up and started them all together. They each picked a favorite timer and it was like a horse race. They cheered their timers and sometimes switched timers in the middle of the race. They did this racing three times and may have gone on longer. The teacher sent them out to recess.*

In these trials it became clear that certain ideas and skills--temperature and the use of a thermometer, formation of a solution and the recognition of schlieren, the use of graph paper for showing relationships--were better repeated in short activity sequences over several years rather than being presented in a single extended investigation. We also found that quantitative work was very difficult for many children, who dealt with numbers only in a rote fashion, applying arithmetic processes without regard to their significance.

A sixth-grader describes periodic motion to Staff Teacher Victoria Durant.

A well-known instance of this difficulty concerned the final temperature of a mixture of warm and cold water. When asked about this qualitatively in terms of warm and cold water, most children predicted a luke-warm mixture. When asked quantitatively in terms of 60 degree and 100 degree water, many children predicted 160 degree water for the mixture, since the two water samples were added together.

Two other aspects of our first efforts promised to lead to difficulties in connection with larger trials or nationwide distribution. One of these derived from the cost and storage needs of the equipment, such as spring scales for weighing, thermometers for accurate temperature measurement, containers for substances to be used in experiments, and chemical and metal specimens to be investigated. The other was the teachers' anxious reactions to the activities which used unfamiliar equipment and introduced unfamiliar ideas.

The Final Edition

The staff concluded that our first efforts aimed at the upper elementary grades had been too technical and demanding. Yet these efforts allowed us to define the domain within which a more promising approach could be formulated. First, we decided to include chemical, thermal, electrical, and mechanical interactions as frequently as possible so the children would be motivated by the wide diversity of phenomena they investigated. Second, we abandoned the third line of the conceptual development chart and introduced new concepts--subsystems, variables, energy sources and receivers, scientific model--that were more appropriate to the children's developmental stage of concrete reasoning. Third, we greatly reduced the need for quantitative comparisons, thus eliminating costly equipment as well as unwarranted reliance on mathematical understandings. These changes automatically made the demands on the teachers more reasonable.

The final edition units used this new approach. They retain the central idea that changes in nature take place because objects interact in reproducible ways under similar conditions. The major scientific concepts used to elaborate the interaction viewpoint are matter and energy, though neither of these is developed as extensively as we once hoped to do. As regards matter, the children investigate the properties and interactions of solid substances, liquids,

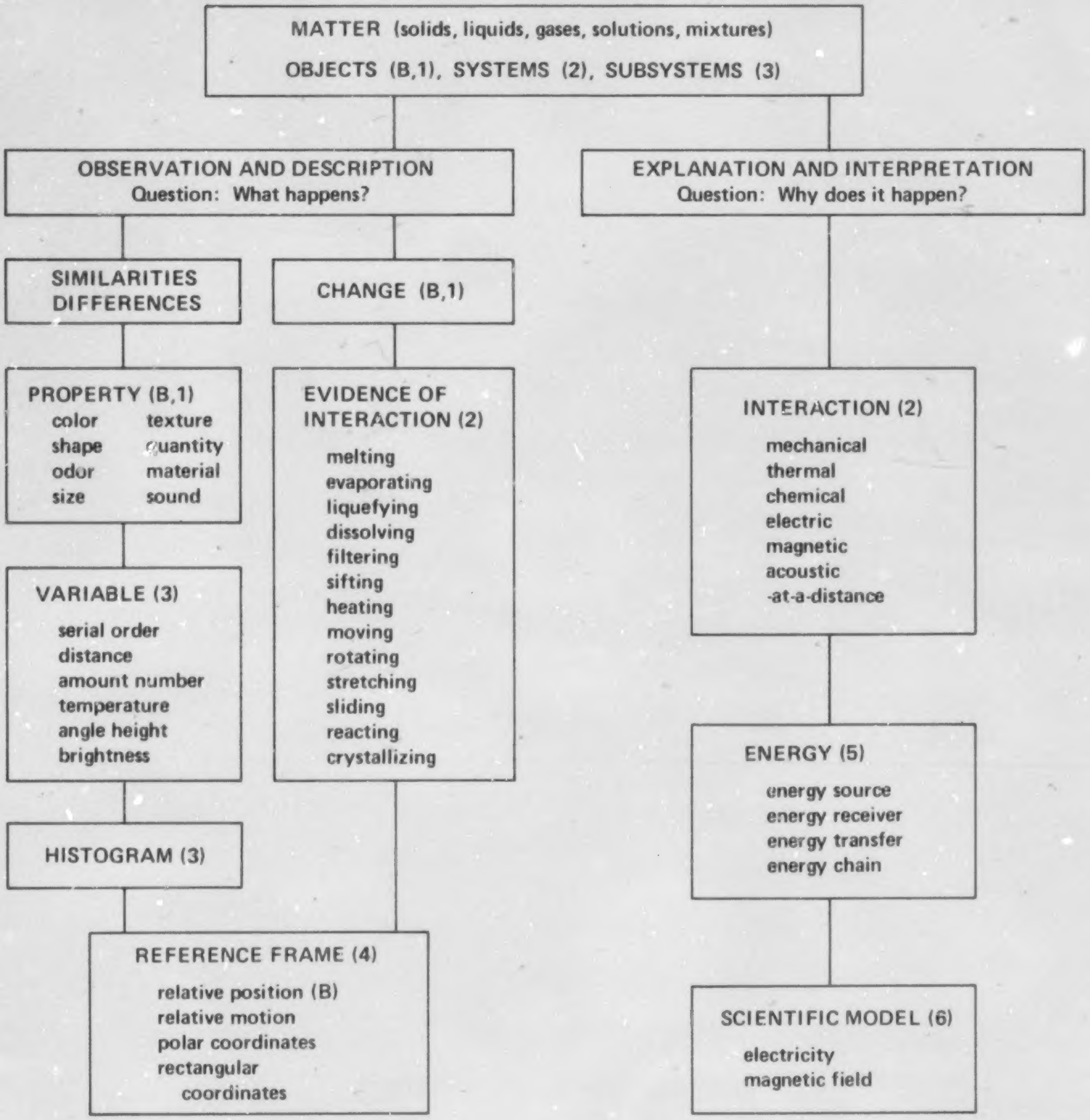
MATTER (solids, liquids, gases, solutions, mixtures)
OBJECTS (B,1), SYSTEMS (2), SUBSYSTEMS (3)
OBSERVATION AND DESCRIPTION
Question: What happens?
EXPLANATION AND INTERPRETATION
Question: Why does it happen?
SIMILARITIES
DIFFERENCES
CHANGE (B,1)
PROPERTY (B,1)
color
texture
shape
quantity
odor
material
size
sound
EVIDENCE OF INTERACTION (2)
melting
evaporating
liquefying
dissolving
filtering
sifting
heating
moving
rotating
stretching
sliding
reacting
crystallizing
INTERACTION (2)
mechanical
thermal
chemical
electric
magnetic
acoustic
-at-a-distance
VARIABLE (3)
serial order
distance
amount number
temperature
angle height
brightness
ENERGY (5)
energy source
energy receiver
energy transfer
energy chain
HISTOGRAM (3)
REFERENCE FRAME (4)
relative position (B)
relative motion
polar coordinates
rectangular coordinates
SCIENTIFIC MODEL (6)
electricity
magnetic field

FIGURE 2. SCIS CONCEPTUAL OVERVIEW CHART, 1974

gases, solutions, and mixtures, but do not formulate models or theories to explain their observations in terms of the structure of matter.

As regards energy, the students investigate mechanical, thermal, and chemical interactions to identify energy sources and receivers. To compare the results of similar experiments, they use the distance moved, ice melted, temperature change, and other intuitive measures of the amount of energy transferred. Yet they are not asked to employ more comprehensive measures of energy that would allow comparison of energy transfers in widely differing experiments.

In addition to the matter and energy concepts, we have found it valuable and appropriate to introduce certain other concepts, such as variable, histogram, reference frame, and scientific model, which we call process-oriented concepts. These four, together with property, change, and system included in the first and second years of the program, do not refer to specialized science content but rather relate to the processes of describing, interpreting evidence, experimenting, and other processes. In fact, they are not unique to natural science but apply to the social sciences as well.

The chart in Figure 2 summarizes the relationships of the major concepts in the final edition of the SCIS physical science sequence. *Matter* at the top indicates the focus on material objects and systems. Just below are the three major concepts--objects, systems, and subsystems--that refer to pieces or aggregations of matter. The numeral beside each term identifies the level in the physical science sequence during which the concept is introduced.

The remainder of the chart is divided into two branches, description on the left and interpretation on the right, like the chart in Figure 1. Similarities and differences under the descriptions are made more specific in terms of certain properties (*Beginnings* and level one) and variables (level three). The functions that can also be used to describe objects (see Figure 1) have been de-emphasized in the final edition because virtually all children have a good grasp of this utilitarian idea. Histograms (level three) are introduced to describe collections of objects or systems.

When variations with time are observed, one speaks of change (*Beginnings* and level one) that may be considered evidence of interaction (level two).

The many types of change investigated by children in the physical science units are listed under the latter heading; melting, evaporating, dissolving, and many others are met repeatedly in life science units as well as in physical science units. The reference frame concept (level four), which is used implicitly though not introduced by name, is placed across both columns of the left part of the chart because it serves to describe position, an example of a property (first taken up in *Beginnings*), as well as motion, an example of change.

We now turn to the right hand side of the chart, where I have placed the explanatory concepts. The first one is interaction (level two), which is illustrated with diverse examples during that year and in subsequent life and physical science units as well. The next interpretive concept, energy, is only introduced in level five, after the children have applied the interaction concept extensively and have also learned to use the additional descriptive concepts of the third and fourth levels.

In fact, energy itself is mentioned only rarely in the program, and the children's tasks are usually expressed in terms of energy sources, energy receivers, and energy transfer that are directly related to objects and observable changes. The last item on the right side is the scientific model (sixth level), which is applied to electric and to magnetic interactions.

In addition to eliminating the concept of function of objects already mentioned above, the final edition does not take up force or entropy which were included in Figure 1, it does not distinguish between reversible and irreversible changes, and it omits evolution. Even though my colleagues and I made some progress in developing teaching activities oriented around these ideas, we found that the results did not justify the costs of equipment, the classroom time required for elementary school children, and the necessary effort in teacher education.

Looking back at Figure 2, I am struck by the fact that the term "physical science sequence" is partially a misnomer. True, the children's investigations are taken overwhelmingly from physical and chemical phenomena. Yet the conceptual framework of major ideas is fundamental to biology, geology, and astronomy as well. In fact, if the focus on matter and energy is eliminated, one is left with a descriptive and explanatory approach that can be used in psychology, sociology, anthropology, and economics to good advantage.

Chapter 5 The SCIS Life Science Sequence — A Case History

by Chester A. Lawson

"How does one build a curriculum?" This question was asked by a visitor from abroad who had the responsibility of redesigning the science curriculum in the schools of his native land. I couldn't answer, of course, because there are no established procedures. There are only historical patterns plus the intuitions, prejudices, faith, and good or bad guesses of the persons who build the curricula. In these days of educational turmoil, it should be an advantage to know how to go about building a curriculum. For this reason I offer the following--not as the final answer to the question, but as an example of how one curriculum was built.

The development of the SCIS life science sequence began in the summer of 1965 when I visited the SCIS headquarters on the University of California's Berkeley campus. During this two week period, I concluded that a biology program for the elementary grades was feasible and that I could help develop one. It is now ten years later and we have had a reasonably successful program in operation in the public schools and in some foreign countries for several years.

The SCIS life science sequence is an ecological program. One of the major objectives is for the sixth grade children to finish the sequence with an understanding, at their cognitive level, of an ecosystem and of man's effect on the worldwide ecosystem.

The selection of ecology was made before the public became generally aware of the subject and we did not consciously anticipate the public's interest. But having selected the basic concept, what could be more logical than a survey of the major events in an ecosystem during the first year, a focus on individual plants and animals during the second year, observations of populations in the third year, then investigations of effects of the environment on plants and animals, followed by new investigations extending parts of the first, second, and third year to produce comprehension of a biotic community? Finally, the capstone--all of the experiences of the previous five years are reinvestigated and integrated into the conceptual scheme called an ecosystem.

The SCIS life science sequence is a logical package where each part is essential and fits all the other parts, producing a unified whole. On examining the finished program, one might conclude erroneously that it was conceived in the mind of the director by logical deduction and then put together as a teaching program by selecting the equipment and materials dictated by the plan. But if this conclusion is incorrect, how was the curriculum constructed? Let us proceed with the story.

Major Understandings

While in Berkeley during the summer of 1965, I wrote the following statement which describes the beginning of the development of a conceptual framework:

> *As I understand the SCIS program, the intent is to help the child to develop literacy in science; to become knowledgeable in the area of science; and to appreciate the viewpoint of the scientist. This task is to be achieved by creating situations where the child, through his own observation and response, discovers the concepts. The child is not told directly, but rather is to be led step by step along the path of discovery.*
>
> *To achieve this goal, the teacher first needs to know exactly what concepts he wants the child to learn. Secondly, he needs to structure the child's experience so that, given a normal child, the child will observe (perceive) the significant relationship and be able to develop the proper ideas from them.*

The next step was to select from the entire field of biology the areas that could be used in the program. The following are the major conceptual systems of modern biology: (1) evolution, (2) Mendelian genetics, (3) cell theory, (4) biochemistry, (5) ecology, (6) taxonomy, and (7) morphology. I realized that these seven concept categories could be subdivided into an almost infinite number of subcategories. Also, some of the categories overlap.

What did we want the child to achieve? What sort of literacy in biology did we expect? The following was our answer:

> *First, we should want the child to become aware of the diverstiy of organisms and of the major groups of animals and plants.*

> *Second, the child should have some understanding of organism-environment relationships; of the view of an organism as a process (called life) that goes on so long as certain materials and energy are available from the environment.*
>
> *Third, the child should know something about the structure of organisms. This means essentially cells, tissues, organs, systems, etc., in both plants and animals, including himself.*
>
> *Fourth, the child should understand that all individual life eventually ceases, but that through reproduction and development, life as a process continues.*
>
> *Fifth, the child should appreciate the function of heredity in maintaining the continuity of kind from generation to generation. This should include Mendelian genetics, at least to the idea of gene as a unit and its relation to the reproductive process.*
>
> *Sixth, the child should understand that organisms do not live alone, but in populations, maintained generation after generation by reproduction and heredity.*
>
> *Seventh, the child should understand that populations also do not live alone, but together with populations of other organisms forming interacting communities; that the community within a physical setting constitutes the environment of the individual organism.*
>
> *Eighth, the child should understand that the environment changes, sometimes slowly, and sometimes quickly; that all individual organisms have some means of adapting to change, but that there are limits to this adaptability; that the limitations are fixed by heredity; that no individual organism can change his own heredity; that through gene mutation the heredity of populations can change with the result that new organisms can be produced that may be better adapted to the new environment; that the environment operates as a selecting mechanism which destroys the non-adapted and nurtures the adapted.*

After identifying the major concepts that the children should understand as a result of the program, the next problem was to specify activities that could be done in the classroom in order to achieve the hoped for understanding. Soon it became clear that the outline contained too much. Something would have to go, but what? Two factors guided our selection of ecology as the area of biology that we could exploit: we could use organisms big enough for the children to observe and handle, and the conceptual scheme of the ecosystem could be presented in a meaningful way at the children's cognitive level.

Thus, by September 1965 we had a conceptual framework that could serve as a guide for the development of the life science program. Before designing lessons on the basis of our guiding scheme, we decided to talk to a sample of elementary school children to learn their ideas about plants, animals, the environment, and other relevant and related matters. We designed a questionnaire to guide us in our individual interviews with first, third, and fifth graders. The results contained few surprises but confirmed what the literature reported about children's concepts in this area.

The Children's Ideas

After completing the interviews, we began planning and testing activities in the classroom. The learning cycle approach of exploration, invention, and discovery (see Chapter 6) to sequencing the activities fitted in well with the needs of the life science sequence. Thus, children would begin by exploring an undifferentiated whole and differentiating this whole through the identification of its parts. Then came the introduction to a pattern by which the parts are interrelated (this frequently is a cause-effect pattern). The last stage involved using the pattern in similar instances. The ecosystem was the "whole" we hoped to investigate. Aquaria and terraria were miniature ecosystems that could be brought into the classroom, investigated, and related to the natural ecosystem outdoors. So that's how we began--with six half-gallon jars.

In our initial explorations with first graders, the half-gallon jar aquaria contained several guppies of both sexes, a few snails, and some aquatic plants. The bottom of each aquarium was covered to a depth of about one inch with fine white sand.

Our initial objectives were modest. We expected that some of the guppies would produce young and that this would permit the children to observe birth. We hoped that the young guppies would grow so that this basic phenomenon of living organisms could be observed. Living things inevitably die; so if this happened, another characteristic of life could be demonstrated. Perhaps if the dead organisms were left in the aquarium, decomposition might be observed and questions could be raised concerning what happens to organisms after death. Movement attracts attention and we thought that by watching the fish and the snails, the children might discover that organisms are sensitive to factors in their environment and behave in certain ways.

The children's first reactions were as anticipated. They clustered about the aquaria, observed the fish, snails, and plants, and commented about what they saw. About fifteen minutes later, the teacher gathered the children around her and asked them to report on what they had observed. After a few comments about the fish and the snails, one child asked, "What is on the bottom of the aquarium?" We hadn't anticipated this question. It was the first of several surprises that we exploited to develop our program.

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Director for Life Sciences Chester A. Lawson listens to a first-grader describing the organism in an aquarium.

The teacher did not answer the question directly. Instead, she asked if any of the other children had any ideas about the identity of the stuff on the bottom of the aquarium. One child said it was sand, but there were other ideas including salt, sugar, chopped up glass, and a sponge.

The process of differentiation of the whole, the aquarium, had begun with the recognition of the known parts--the fish, the snails, and the water plants. It now continued with an observable but unidentified element. The teacher could have satisfied the children by acting as an authority and telling them that the stuff was sand, but this would have violated one of the premises upon which we hoped to build our program. We wanted the children to discover as much as possible by their own resources--by suggesting their own ideas (hypotheses) and by testing these ideas against their own observations. To permit this, the teacher scooped some of the sand out of the aquarium, placed it in a shallow dish and set it aside for further observation by the children.

The next day, the teacher returned to class with clearly labeled packages of sand, sugar, and salt. After showing the labeled packages to the children, she poured some of each into separate dishes which she labeled and placed beside the sample of the stuff taken from the aquarium. The children compared the samples and concluded that the stuff from the aquarium was sand.

The teacher then took four empty half-gallon jars. In one she placed a sample of salt, in another sugar, in another some sand. She left the fourth jar empty. She then filled all four jars about two-thirds full of water and stirred. The children watched and noticed that the salt and sugar disappeared but that the sand did not. This supported their conclusion that the stuff on the bottom of the aquarium was sand.

As time went on, other observations of the children led to further questions. One of these was occasioned by the development of an algae bloom in the aquaria that had been placed near the windows. The children noticed the "green water," and wanted to know what caused it. Following up the question we introduced algae, *Daphnia,* the major anatomical features of *Daphnia* with particular emphasis on the digestive tract, *Daphnia* eating algae and excreting feces. By feeding *Daphnia* to guppies, we introduced the concept of the food chain--algae, *Daphnia,* guppies.

The second observation of significance arose from the accumulation of organic detritus on the sand of the aquaria. Again, the children observed it and wanted to know what "that black stuff" was. Again, the teacher did not tell them what it was, but used their previous observations of feces from *Daphnia* and the one or two fish that had died to enable the children to discover the source of the detritus.

The entire first-year program did not depend only on the questions that children asked. The teacher gave the children seeds to compare and plant in soil where they could germinate. Nothing specific was made of the observations of the seedlings. The children observed growth and some of the differences among a variety of common garden plants. In the second-year program, a more detailed study of plants would lead to the concept of life cycle.

The second-year program concentrated on the characteristics of living versus nonliving objects and on the characteristics of plants and animals. The second grade children in Berkeley were similar to the children of this age described in the literature in that they identified life with movement, were limited in their definitions of animal, and believed that plants were not alive. In order to improve the children's understanding of living things, we asked them to plant seeds, to care for and observe plants germinate, grow, produce flowers, fruit, and seeds. The children also observed frog eggs develop into tadpoles, which changed into adult frogs. They identified the various stages of the fruit fly and mealworm life cycle. From these clues, we hoped to continue to the upper grades.

The procedure we used in developing the SCIS life science program was different from that of any other curriculum development project I had previously experienced. Most science curriculum projects include summer writing conferences where "experts" congregate for eight to ten weeks and produce textbooks, laboratory guides, and other curriculum materials. The products are the result of the "experts' " past experience and are not tested during production but only later--and then by persons other than the "expert" authors. More details of our approach are included in Chapter 7.

Minor Setbacks

By August 1966, the first two years of the program were established in outline if not in every detail, but the plans for grades three, four, and five were nebulous. Some ideas suggested for grades three and four included comparative studies of growth, development, and reproduction. Also suggested were the effects of environmental-physical factors on organisms.

One idea that gained great prominence in our thinking was the photosynthesis-respiration relation of plants and animals. Since no ecosystem could exist without oxygen-carbon dioxide exchange between plants and animals, we thought that this phenomenon should be included somewhere in the program. We worked out simple experiments to be performed by the children, the results of which would convince them that plants produced a gas needed by animals and that animals produced a gas needed by plants. On the basis of the results of these experiments, we hoped to introduce the photosynthesis-respiration relationship.

We worked with a third grade in Berkeley. We started with bubble productions by *Anacharis (Elodea)* under lights, and continued with other experiments, all of which we hoped would spark a response that could be developed into a functional learning situation. We worked for two months and finally concluded that we had failed. The following is taken from an observer report dated March 1, 1967:

> *As we had hoped to use this setup (an experiment with bromothymol blue) to show the children what they were unable to conceptualize, we felt that we should discontinue this series for the present. It would appear that formal thinking is necessary for a real understanding of the relationship between plants and animals and respiration and photosynthesis. We felt that this was a bit beyond third grade. It would seem more advisable to present more highly visible concepts, such as that of population, in the third grade and to present the idea of photosynthesis and respiration in conjunction with cycles and recycling in the upper grades. This would hopefully be when the children are more able to handle abstract ideas and relationships.*

In April, 1967 we started again with a new group of third-graders using miniature ecosystems containing aged tap water, gravel, some detritus, a little soil, *Elodea*, ten to twelve fronds of *Lemna*, four to five snails, a few aphids, and approximately twenty-five *Daphnia*. Several *Hydra* were added to three jars.

We hoped the children would identify all the organisms with the possible exception of *Hydra*. We hoped that the children would note after several days that the *Daphnia* had disappeared in some aquaria and not in others, and that they would raise questions about this discrepancy. From this situation we expected to introduce some understanding of a population as a number of organisms of the same kind that could increase or decrease. Also, we intended to use the *Hydra-Daphnia* feeding relations to demonstrate the food dependency of one population on another.

This approach worked, and the third-year program eventually became the trial edition of *Populations*. Since then, the activities have been reordered in sequence and damsel fly larvae have replaced the *Hydra*, which were hard to see and difficult to maintain.

One path that ended in failure was an attempt to follow up the detritus experience in *Organisms*. During the first year of exploratory teaching, the aquaria that we had brought into the classroom gradually accumulated a visible quantity of detritus on and through the sand in the bottom. The children noticed the detritus and asked where the "black stuff" came from. We followed this question with a series of experiments that gave the children some answers concerning the origin of detritus.

We hoped that the children at a later age, say in the fifth grade, would still be interested in detritus so that we could use this as a path to investigation of the relation of bacteria and molds to decomposition in an ecosystem. Rather than wait for the weeks for detritus to accumulate in aquaria, we built a series of aquaria over a period of time. When we took them into the classroom one aquarium was one day old, another was two weeks old, another two months old, another four months old. We presented a fifth aquarium with an unidentified age.

We hoped the children would compare the aquaria and ask questions about the differences. They didn't. The children only showed interest in the one-day-old aquarium. Now the reason seemed obvious! The new aquarium had clean white sand; the plants were a fresh green against a background of white; and the fish were colorful. The new aquarium was aesthetically pleasing in contrast to the other, older aquaria.

Despite the children's initial lack of interest in the products of decomposition in the aquaria, we persisted in our attempt to stimulate interest in molds and bacteria. The children eventually responded when they observed protozoa in mixed cultures. However, we were unable to follow up this interest because, aside from the microscopic organisms themselves, there was little that the children could see. The attempt to build a complete unit on microorganisms, decomposition, and detritus was dropped. Later we included an activity on decomposition in the fifth-year unit, *Communities*.

Completing the Program

The idea of studying the effects physical factors of the environment have on plants and animals had been associated with grades three and four from the beginning. Now that *Populations* usurped the third-year program, we decided to concentrate on physical factors during the fourth year. Associated with physical factors was the idea that organisms are adapted to live within certain ranges of light, temperature, moisture, and so on. Experiments with plants and animals exposed to physical factors in varying intensity formed the basis of the *Environments* unit on the fourth level of the sequence.

The fifth-year unit's major emphasis concerned the transfer of food within a biotic community. The children had been introduced to food chains in the first year, and they observed them again in the third year. We wondered whether they would be bored by meeting food chains again in the fifth year. They weren't. We believe the reason was that we used different organisms and treated the food chain at a more abstract level. Eventually, the title at the fifth-level unit became *Communities*.

The logical subject matter for the sixth and final year's program was now clear. It had to be concerned with a review of all preceding units and activities tying together the various concepts into an understanding of an ecosystem.

One incident in the development of the *Ecosystems* unit is of special interest. We started exploratory teaching by having a sixth-grade class in Berkeley set up an experiment where snails and the aquatic plant, *Anacharis*, were contained in one vial, snails alone in another vial, and *Anacharis* alone in another vial. During the discussion before the children set up the experiment, a child upset our plans for the introductory activity by volunteering, "In the fourth grade we were told that animals can't survive without plants and that plants can't live without animals. You know, ecology. Plants need the animals and vice versa."

We had hoped to raise the question of dependency of plants and animals as a result of our experiments with snails and *Anacharis*. However, since the children already had been told about the plant-animal relationship, we thought there was no point in the experiment that we had planned. We changed our tactics. We asked the children what they knew about the interdependence of plants and animals. They responded:

1. Plants use carbon dioxide and produce oxygen.
2. Animals use oxygen and produce carbon dioxide.

No one suggested that plants in the dark use oxygen and produce carbon dioxide, and we didn't tell them. Instead, we explained that many experiments were done by scientists to test ideas (theories) proposed by others, and that the class would do experiments to test the statements listed above concerning the oxygen-carbon dioxide relation of plants and animals.

First, we introduced bromothymol blue as an indicator of the presence of carbon dioxide. (As no cheap and simple method of determining the presence or absence of oxygen was available, we limited the experiments to those concerned with carbon dioxide.) The children's experiments confirmed the idea that animals produce carbon dioxide. They also confirmed that plants use carbon dioxide. However, this was true only when the plants were kept in the light. The results of the experiments with plants in the dark indicated that these plants did not use carbon dioxide. Instead, they indicated that plants produce it!

Here was evidence that contradicted what the children already "knew"--only they didn't believe it. They explained away the data by various *ad hoc* hypotheses: "The water in the vials was bad;" "The plants were dead;" "The caps on the vials were loose;" and so on. One boy ventured to suggest that maybe the plants really did produce carbon dioxide in the dark, yet he was scorned into silence by his classmates.

I was reminded of the many times in the past when scientists refused to believe discoveries of other scientists because they were contrary to the ideas held by the majority. Apparently, it is a human trait to greet new ideas with scepticism and to change established ideas very slowly. Eventually, even our sixth-graders accepted the idea that plants produce carbon dioxide in the dark, but only after very carefully repeating the experiments.

When we began developing the life science program in the first grade, the public was largely unaware of ecology and pollution. By the time we were working on the sixth-year ecosystem unit, pollution was a household word. For this reason we added several activities to the *Ecosystems* unit that demonstrated some of the factors that cause pollution. We hoped that children could discover why pollution and overpopulation were dangerous--because they upset the balance of interactions within the ecosystem.

The SCIS life science sequence develops the ecosystem conceptual scheme. It does this on the basis of direct "hands-on" experiences of children with plants and animals. Some of these experiences involve controlled experiments. During the six years from grade one to grade six, few of the children become expert experimenters; still, they do learn the function of a control and are introduced to the principle that answers to scientific questions come from data and not from teachers or textbooks. We hope that there will be some carryover of this principle to the social problems that confront man.

Chapter 6 Approaches to Teaching

The teacher of the SCIS program must adjust classroom organization and procedures to provide for substantial student autonomy and inquiry. The teacher's guides and *SCIS Teacher's Handbook* describe some of the techniques useful for discussions, demonstrations, and laboratory work. Several other aspects of teaching should also be kept in mind. They are the phrasing of questions to challenge inquiry rather than the recall of facts, the encouragement of peer interaction to help children learn from one another's ideas, and a deliberate but not tedious pacing of the activities with attention to individual variations in the learning rate of children.

Three inquiry-oriented teaching strategies were developed in connection with the SCIS program but have much wider potential application. They are wait-time, developed by coordinator Mary Budd Rowe of the SCIS trial center in New York; the learning cycle, originated by Karplus and Atkin and expanded by the SCIS staff; and Piaget's developmental theory adapted to teaching strategies by the SCIS staff.

Wait-time

During classroom observations, Rowe found that the average time allowed a child to begin answering a question was about one second. When children did not respond quickly enough, most teachers would repeat the question, ask another question, answer their own question, or call on another child. Only the fastest children could reply in the very short time allowed, and they could only provide brief and superficial answers.

While a fast pace in questioning may be suitable for some very specialized instructional purposes, it is clearly unsuitable for teachers who are conducting inquiry-oriented science lessons. The basic notion underlying the SCIS program is that children can find needed information from investigating the learning materials and not from reading the teacher's mind. If that is the case, the children must have time to observe their experimental materials carefully. Also, the ideas suggested by their observations may require time to articulate and may be modified when other children comment before the teacher changes the subject.

In Rowe's investigation, teachers extended their wait-time--the time before they spoke again--to five or ten seconds for allowing a child to respond after they had asked a question; they also lengthened the interval after a child's reply and before they gave an acknowledgment. The results were very worthwhile. Children expressed their thoughts in whole sentences rather than single words. They tended to speculate on possibilities rather than merely confining themselves to the narrow subject matter of the question. Their self-confidence increased and they brought in evidence to justify their replies. During the seconds of silence after one child's answer, other children would often describe concurring or contradictory ideas and might ask questions of the previous speaker. Many children began to participate who had previously remained silent.

One additional beneficial result was reported: the more leisurely pace of the proceedings allowed the teachers to be more thoughtful in framing their questions or statements. They asked fewer rhetorical questions; they invited the children to speculate, evaluate, or interpret; and they sometimes even allowed the children to proceed with the discussion among themselves.

The control the teacher exerts over the classroom agenda can either limit or enhance the children's autonomy. Silence during a "discussion" is very threatening to the discussion leader. Yet silence must be endured to create opportunities for participation by all, whether they be impulsive or thoughtful, assertive or shy, factual or fanciful.

The Learning Cycle

To help teachers plan their own role in relation to the children's science investigations, the activities follow a cyclic pattern of three phases that are called exploration, invention, and discovery. This so-called learning cycle incorporates both the experiential and conceptual aspects of the teaching program and reflects three modern theories of learning and development described near the end of this section.

To gather experience about natural phenomena, the students may observe changes of phase when materials are heated or cooled, the motion of magnetized objects interacting without physical contact, the color of plant seedlings growing in a dark closet, the formation of mold on the body of a dead guppy, and the details of structure that become visible when a wood or mineral specimen is examined with a magnifying glass. In all these areas it is essential that the experiences be direct ones, that the students have an opportunity to act upon the materials and thereby influence what happens. Seeing photographs or reading descriptions are completely inadequate substitutes for observation and action. To gain this necessary experience of their natural environment, children must have sufficient autonomy to follow their own ideas when investigating or observing.

Two children demonstrate interaction-at-a-distance while Staff Teacher Cynthia Ann Powell watches.

Contrasted to the above is the conceptual side of science--for instance, the idea of interaction as the reason for observed changes. In Chapters 4 and 5 we have described the associated concepts of matter and energy, organisms and ecosystems, that form the core of the physical and life science sequences. The conceptualization of relationships and the use of these terms are clearly not something that children will arrive at by themselves, nor is it likely that they will attach particular significance to "objects doing something to each other."

With respect to the concepts, therefore, it is necessary that the teacher give simple, unambiguous definitions in terms the children can understand, and with reference to examples that are familiar to them. In planning curriculum materials, therefore, one must identify in advance those activities that require clear directions or explanations from the teacher. These expositions form conceptual input for the children.

An educational program requires both autonomous experiences and conceptual input. Utilization of the learning cycle assures their balance and suitable alternation. Exploration is the first stage of the learning cycle. Children learn through their own spontaneous behavior relative to objects and events, that is, by handling objects and experimenting with them. Children explore materials with minimal guidance in the form of instructions or specific questions. The materials are always carefully chosen to be easily used and to generate certain questions that the children have not asked before. Exploration affords the teacher informal opportunities for observing what individual children actually do, listening to them describe their ideas to one another, occasionally asking them questions about their findings, and encouraging them to try further experiments.

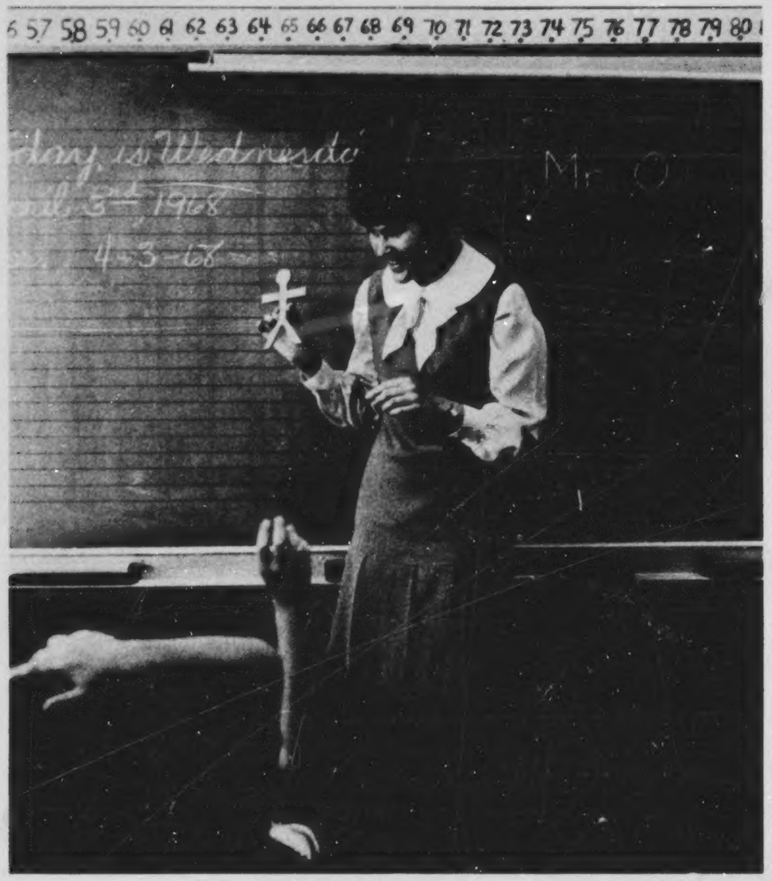
Invention is the second stage of the learning cycle. Children learn as the teacher provides a definition or term for a new concept, while illustrating with concrete examples from the children's prior explorations. The teacher is clear and explicit while explaining and repeats if necessary. To give the children prompt opportunities for using the new concept, the teacher encourages them to identify examples in their everyday life or their recent science activities. These examples also give the teacher feedback concerning the children's understanding. The teacher's role during invention is more directive than during exploration or discovery.

Discovery is the third and last stage of the learning cycle. It refers to activities in which children discern a new application for the concept previously explained in an invention session. Several different discovery activities are suggested in the teacher's guides following each invention lesson. The children's discovery experiences enlarge and refine the concept's meaning and also enable the teacher to conduct further diagnostic observations concerning each child's understanding.

Each concept introduced in the SCIS program is at the center of a learning cycle. The ideas of energy source and energy receiver, for instance, are first encountered by the children intuitively--without identification or naming--as they experiment with rotoplanes (rotoplanes consist of a horizontal platform, free to turn around a vertical axis, that may be propelled by a push from the hand or by means of rubber band-driven propellers). The children's eagerness to achieve a high turning rate leads them to use several rubber bands, to wind these up tightly, and to orient the propellers for maximum thrust. In other words, the children are concerned with controlling the amount of energy transferred to the platform, but do not yet have terminology for articulating their aims on this abstract level. This activity is the exploration phase of the learning cycle.

Next comes invention. While operating a rotoplane with which all children are now familiar, the teacher describes the phenomenon in terms of energy being transferred from hand to propeller and to rubber band (while it is being wound up), later from rubber band to propeller to air and platform (while it is running freely). The teacher tells the children that at first the hand served as energy source and the rubber band as energy receiver, but that later the rubber band was the energy source and the platform and air were both receivers. Other examples the teacher demonstrates are a spring-operated toy, a flashlight, and a candle; each time, the energy source and energy receiver are identified, at first by the teacher, later by children who have grasped the ideas. Note how this explanation not only introduces the terms, but also demonstrates that source and receiver are defined in relation to a particular energy transfer process, that there may be multiple receivers, and that different forms of energy exist.

The concluding phase of the learning cycle is discovery--application of the new concept in a variety of investigations. The children's activities involve consciously controlling energy sources and receivers in experiments with the rotoplane. They also work with warm and cold water, spheres rolling down inclined planes, and rubber stoppers propelled from a small plastic syringe barrel.



Staff Teacher Joan Coffman Randle introduces Mr. O to a class of fourth-graders.

Another example of the learning cycle can be found in the *Populations* unit. Here the children initially culture *Daphnia* and aphids, observe the behavior of these organisms when there are few and when there are many, and daily chart the numbers of each that are alive and visible. After these exploratory activities have been pursued for two or three weeks, the teacher explains that a group of organisms of the same kind living together and interacting with one another is called a population. Thus the *Daphnia* in each vial are a *Daphnia* population, and the aphids on each pea plant are an aphid population. This explanation is the invention. For discovery, the children continue to observe their

Daphnia and aphid populations, and also construct terraria in which they later investigate populations of clover, grass, mustard, and crickets. Note again, as in the first example dealing with energy sources and receivers, how the multiple examples are intended to illustrate the breadth of the concept.

The two examples we have given illustrate learning cycles that may take from two to four weeks of instruction, with one or more class periods for exploration, one period for invention, and then two to six or ten periods for discovery. One SCIS unit may include three to five learning cycles of this kind. The learning cycle structure helps the teacher to define his role appropriately for each phase. It also helps prevent the too rapid introduction of new ideas, since several discovery and exploration sessions occur between successive invention lessons.

Beyond the SCIS program, the learning cycle can be applied in other curriculum areas, as well as in secondary school, college, and continuing education. What is the principal message of this idea? We believe the message is three-fold: first, the instructor should clearly plan what he will tell the students (conceptual input), and distinguish that from what the students are able to learn for themselves at their own initiative (autonomous experience); second, the instructor should deliver his conceptual input neither at the beginning nor at the end of the instructional sequence, because that would prevent exploration or discovery; third, program segments preceding and following the input should provide for a substantial amount of autonomous activity by the learners so they can relate the new ideas to their previous experience and their preconceptions.

We have not yet pointed out how the learning cycle is related to theories of intellectual development and learning. To do so, we shall first distinguish among three major types of theories, which can be characterized as follows.

The "learning-by-conditioning" theory views the learner's behavior as a response to a well-planned stimulus. With repetition, practice, and suitable reinforcement, the learner will exhibit the desired behavior. Note that in this theory there is no room for spontaneous or creative expression by the student. Everything of educational value reflects the inputs accumulated during the teaching program.

The "learning-by-discovery" theory claims that everything of which an individual is capable is latent within him. The educational program must give him opportunities to express these latent tendencies, but should not provide any input that might inhibit or redirect his natural inclinations. Given a sufficiently rich environment, the learner will discover the properties of objects, conditions under which phenomena take place, and general principles relating the isolated incidents and observations in his experiments and investigations.

The "learning-by-equilibration" theory, associated with Jean Piaget and described somewhat more extensively in the next section, views the individual as capable of mental operations which function in a self-sustaining feedback loop (equilibrium) as he acts on his environment and receives stimuli in return. When the feedback loop is disturbed by events that do not fit the scheme (disequilibrium), changes in the mental operations ultimately lead to more powerful mental operations that can cope successfully with a larger class of events (equilibration).

Note now how the learning cycle approach utilizes the three learning theories. Exploration is in accord with "learning-by-discovery" and "learning-by-equilibration." It allows the learner to impose his ideas and preconceptions on the subject matter to be investigated. If he comes up with a successful new idea, more power to him. At the same time, the exploration should create some disequilibrium as students are challenged by new experiences.

Invention is in accord with the "learning-by-equilibration" theory, as the new idea introduced at that time suggests a way for the learner to resolve his disequilibrium.

Discovery is in accord with "learning-by-equilibration," and also with the "learning-by-conditioning" view that repetition and practice are necessary for learning. It is essential, however, that the repetition and practice occur largely through self-directed activities by the learner. Then he will actually resolve his disequilibrium by interacting with the experimental materials and establishing a new feedback pattern for his observations and actions. Therefore, repetition and practice occur at the conceptual level, not at the activity level. Thus, discovery activities in *Energy Sources* all involve transfer of energy but make use of highly diversified laboratory materials and manipulative skills.

Piaget's Theory and Science Teaching

Piaget's developmental theory was derived from the predictions, descriptions, explanations, and procedures of children facing various tasks dealing with their natural environment. Since children encounter similar tasks in science, Piaget's classification of their behaviors is very suggestive for developers of an elementary school science program.

Piaget's theory identifies certain developmental stages in the reasoning patterns of a growing child. Those most appropriate to the elementary school level are the preoperational stage characteristic of the preschool and primary grade child, and the concrete operational stage characteristic of the pupil in the middle and upper grades. Ten years ago, there was already substantial literature concerning the logical reasoning of these children, and the design of the SCIS units benefited from the work that had been done. Unfortunately, the transition from concrete to formal thought, which some children begin during the upper elementary grades, was not documented nearly as well. As a result, the trials involved in the development of the upper grade units were more numerous and tended to overestimate the children's capacities.

The conceptual themes and activities in the SCIS program were designed to match the intellectual development of elementary school children. Thus, the major concepts deal with causality (interaction), class inclusion (systems/subsystems/objects, communities/populations/organisms), classification (objects/properties), serial ordering (comparison sign) and temporal ordering (life cycle), conservation (keeping track of a system), multiple viewpoints (Mr. O), transformation (evidence of interaction), and other concrete operations. At the same time, account was taken of the fact that children in a learning group are likely to be at differing stages. Most of the SCIS investigations, therefore, are designed to enable a child to find a challenge and succeed in meeting it regardless of his developmental stage, with success being defined in terms of the child and not in any normative fashion.

Thus, primary grade children working with buttons of many colors, shapes, and materials may arrange them in pretty patterns (preoperational), sort them into several groups according to a property (concrete operational), or construct a classification system that recognizes colors, shapes, and materials hierarchically (formal operational). As another example, consider the pulley sets included in a second-year unit. Some children may assemble a pulley system and try to make the pulleys turn as fast as they can (preoperational), others may compare the turning rates of pulleys of various sizes (concrete operational), while still others may carefully observe the relative turning rates of two different-sized pulleys and then predict the outcome of as yet untried combinations (formal operational). Though extremely few formal operational students are likely to come into contact with these activities, the existence of these challenges will be a source of intellectual stimulation for the concrete operational children using them.

A third example may be found in the investigation of electric circuits in the sixth-year physical science unit. A few of the students may strive to light the bulb as brightly as possible, perhaps burning it out through a trial-and-error process without regard for the necessary conditions that brought about this result (preoperational). Most of the students in a class will probably recognize the conditions that result in open or closed circuits and use them reliably to classify objects as conductors and nonconductors (concrete operational). Finally, some of the students will contribute ideas to the formulation of a scientific model for explaining the electric energy transfer in terms of electricity flowing through the wires (formal operational).

In each case the teacher will try to identify the child's developmental stage from his questions, answers, and behavior with materials, then guide him gently toward more advanced reasoning. And this is where the phenomena in the science program are especially valuable, for regularities in the physical universe provide a base for the Piagetian operations. For example, children may observe that ice-water mixtures are always close to the temperature of 0°C as long as ice is present, whereas water without ice may have any temperature in a very wide range. Children can deduce consequences from this fact and set up experiments to test the consequences. At a certain point in their experience, this repeated observation will be tested against their everyday expectation that anything put over a fire, even ice-water mixtures, will immediately get warmer, and anything put into the freezer will immediately get much colder.

In other words, the school science program can contribute to learning and development in these ways: (1) observations and investigations provide children with experience of the physical world, extending their knowledge and acquainting them with certain regular patterns of behavior of the natural universe; (2) the social environment in the classroom allows children to learn from one another and from the teacher by asking questions, observing others, and listening to explanations; (3) the content and form of the activities lead children to reorganize their reasoning as they recognize its limitations, discover more fruitful procedures, and apply their ideas autonomously to a variety of situations. These three contributions, taken together, result in what Piaget has called equilibration, the active process whereby a person responds to inadequacies in his own thinking through the formation, trial, and evaluation of new approaches.

The combination of autonomy and input provided by the learning cycle has been designed to facilitate equilibration. In addition, certain other procedures may be used, as occasion permits, in any teaching program that allows for some student autonomy:

1. Grouping children heterogeneously and encouraging peer interactions;
2. Calling attention to surprising or "discrepant" events, or to disagreements among children's reports;
3. Challenging pupils to explain and/or justify their conclusions, predictions, and inferences;
4. Proposing unsatisfactory hypotheses or invalid references to encourage the children to evaluate their teacher's ideas, not just to memorize them;
5. Using concrete examples accompanied by demonstrations to introduce a new term (the concepts of energy and reference frame were not introduced in the SCIS program because the project staff could not find suitable definitions; energy source and reference object, which were used instead, could be explained with concrete examples);
6. Relating a transformation, such as the melting of ice or the throwing of a ball, to the reverse transformation (freezing of water, stopping of the ball).

We should like to point out in addition that the above list, though intended for elementary schools, has been adapted for use with secondary school and college students who primarily employ concrete reasoning patterns.

In conclusion, we should mention that autonomy has great motivational value as well as contributing to cognitive growth. Doing something because you want to do it, and doing it the way you want to are powerful incentives. After a class visit by SCIS staff, one student wrote, "I, ... myself have really enjoyed you here to-day. And I have really learned how to say and write what I and only I think, with no one else to try to tell me. So I hope you come back again." Both wait-time and the learning cycle are complementary ways of increasing student autonomy but still providing teacher leadership to avoid the confusion that results when students do not know what to do, or are trying to do something they do not understand.

Chapter 7 The Development Process

Six children were selected for the first group to view a device which, when rolled across the floor, reverses its direction of motion and, after making several shorter and shorter trips, finally stops. The teacher rolled the device on the floor twice, each time calling attention to the object's motion and design. The children expressed delight and speculated as to why the object behaved as it did. Without letting the children touch the device, it was placed in a box. The children were asked if they would like to construct such a device, given the materials. The response was an enthusiastic "yes." The following materials were distributed to each team (two children): a hollow paper cylinder (5-1/2"

Fourth-graders watch a mysterious device rolling across the floor during exploratory teaching.

> *x 2"), a rubber band (1/8" x 4"), two masonite disks (2" diameter), a paper clip (fashioned into a hook), and a lead weight (2" x 1/8").*
>
> *After 6-8 minutes all of the teams had successfully constructed a device. One team was a little slower than the other two but profited from the mistakes of the other teams. The children were asked to compare the performance of their device to the one the teacher had shown and to think of ways of improving their device. One team thought a rearrangement of the rubber band would improve the device. The teacher suggested they might use a different weight, either heavier or lighter. Three different weights and additional rubber bands were made available to the children. The children tried various combinations and after 8-10 minutes, had constructed devices which performed as well as the one shown by the teacher. One boy offered an excellent detailed description of how the device worked. The other children agreed.*

This account by SCIS staff member Marshall Montgomery of his thirty-minute meeting with fourth graders on December 12, 1967, describes his first presentation of the device to elementary school children. He had invented the device and designed the activity as part of his contribution to the development of the *Approaches to Equilibrium* unit. In this rather artificial setting of only six children, Montgomery was not really teaching but rather observing closely how the children handled the materials and what ideas they applied to their task. Note that the original demonstration served to arouse the children's curiosity and not to show them how the device worked.

In a similar subsequent activity with nine more children, Montgomery found that the construction might take up to fifteen minutes, that children who work in isolation take longer because they do not profit from their classmates' experience, and that some children ascribe the device's operation to magnets.

The investigation we have just described was characteristic of the very early stages in the development process that led to the SCIS units. Altogether, as many as fifteen distinct steps were involved in the following sequence, where the three key teaching stages are underlined:

1. Brainstorming to create ideas for activities and investigations compatible with the conceptual organization of the unit.
2. Laboratory investigation by project staff of phenomena and devices proposed for inclusion in the unit. Redesign or elimination of materials that appear too difficult to manipulate, too hard to observe, or too unreliable using the equipment and facilities available in elementary school classrooms.
3. Exploratory teaching based on a teaching outline and discussion within the development team.
4. Preparation of a written draft for the trial edition teacher's guide and student manual. (Sometimes this step accompanied the exploratory teaching.)
5. In-house review, revision, and editing of the trial edition manuscript. Design and manufacture of trial edition equipment for about three hundred students.
6. Trial teaching in the Berkeley area by regular classroom teachers.
7. Evaluation of the trial teaching based on observer reports, teacher feedback, used student manuals, and testing of students.
8. Redesign of the conceptual organization, teaching activities, student manual, and/or equipment, accompanied by exploratory teaching, and leading to preparation of a new manuscript for the preliminary edition. (Some units were published in a revised trial edition and were cycled through steps 5, 6, 7, and 8 a second time.)
9. In-house review, revision, and editing of the preliminary edition manuscript.
10. Publisher's editing of the manuscript and apparatus maker's design of commercial equipment for the preliminary edition.
11. Field test of the preliminary edition in the five national SCIS trial centers.
12. Evaluation of the field test based on observer reports, recommendations of trial center coordinators, suggestions from trial center teachers, review of used student manuals, and testing of students. (The upper-grade units, which were not published in a preliminary edition, were field-tested in the trial edition.)
13. Redesign of the conceptual organization, teaching activities, student manual, and/or equipment, accompanied by exploratory teaching, and leading to a new manuscript for the final edition.

14. In-house review, revision, and editing of the final-edition manuscript.
15. Publisher's editing of the manuscript and apparatus maker's design of commercial equipment for the final edition.

The actual occurrence of classroom trials and publication for each SCIS unit are given in the chart in Appendix E.

Personnel

Keys to the success of the SCIS project were the inventiveness, good grasp of teaching strategy, and good judgment of the staff members serving on the development teams. From its very early days, the Study pursued a policy of bringing together outstanding individuals with backgrounds in many different areas bearing on elementary science instruction. The principal developers on the SCIS staff included university scientists, high school science teachers, and elementary school teachers. As the project grew they were assisted by psychologists, science educators, editors, filmmakers, artists, designers, technicians, and secretaries. Collaborating during the 1963-64 year in Berkeley, for instance, were Director Robert Karplus, a physicist, Assistant Director Herbert D. Thier, a former secondary school physics teacher and school administrator, James Eakin, a minister and former secondary school English teacher, Patricia Summers, an elementary school teacher without special science background, and Christine Nahnsen, secretary and editor.

How could a teacher without science background help the project? Mrs. Summers and other teachers who later worked on the SCIS materials played a key role by serving as the first critics of new content ideas such as solutions or equilibrium and new procedures such as using filter paper or constructing a terrarium. As the scientists and science teachers on the staff taught the new material to their untutored colleagues, they were compelled to search their minds thoroughly for the simplest and clearest ways of describing it. If their explanations were inadequate--well, then there was no use in pursuing these same ideas for elementary school pupils and their regular teachers.

Each unit's development team involved very close working relations among the individuals, but certain primary responsibilities were divided. Thus, the scientists were concerned with providing leadership as regards the conceptual development, the secondary science teachers devised most laboratory procedures and equipment, and the elementary school teachers outlined the classroom procedures. During the preparation of manuscripts (steps 4, 5, 8, 9, 13, and 14), of course, every team member contributed to all aspects of the unit. Frequent discussions among the entire project staff helped to coordinate and refine the content of the units and establish priorities regarding the general objectives.

Personnel recruitment was carried out very carefully, principally by Assistant Director Thier, through personal recommendations of scientists and science educators sympathetic to SCIS philosophy. Every candidate for a continuing position was interviewed and then observed teaching a group of students; his/her teaching style was evaluated in light of its suitability for an inquiry-oriented program. The Study depended on a long-term staff working year-round, rather than on summer writing groups, primarily for five reasons: (1) the slow pace at which children can accept truly new ideas makes summers inadequate for experimental teaching; (2) the interaction of staff with pupils, which results in imaginative new teaching approaches, cannot be compressed into a few weeks' time; (3) the need for pupils at each grade level who have prior SCIS experience cannot be satisfied during voluntary summer schools; (4) the staff members who conceive a unit must be available to follow the classroom trials during the academic year and interpret the feedback for revision; (5) the education of staff members requires several months of experience as part of a development team.

Invention of Activities (Steps 1 and 2)

Science activities compatible with the general SCIS goal of scientific literacy had to hold the children's interest, stimulate them intellectually, have significant science content, fit the conceptual scheme of a unit, be safe, not require costly equipment, have a reliable outcome, and be readily understood by teachers. Inventing such activities was a very demanding assignment. All project staff members were therefore always encouraged to propose ideas for such activities, and very considerable staff time went into considering, reviewing, laboratory testing, and further developing these ideas. As we mentioned above, the scientifically untrained elementary school teachers and secretaries on the project staff served as the first "students" using the new activity after it had been worked out by its inventors.

It is clear that laboratory facilities, cultures of living organisms, and a design shop were important resources of the project. Here the whirly bird, rotoplane, stopper popper, bleach battery, and aquarium-terrarium systems were first constructed, and the behavior of beetles, snails, and isopods subjected to various environmental conditions was first investigated. Unless a clear objection arose during these laboratory tests, proposed activities were tried out in elementary school classrooms, where the developers could get feedback from the children rather than having to conform to the theoretical concerns of their colleagues. After these trials, many suggestions were quietly dropped because of operational or pedagogical problems, or because they were not as effective as other proposals dealing with the same ideas.

Classroom Trials

The project's pragmatic approach of actually trying out activities repeatedly in the classroom, using the children's questions to extend the investigations, and helping teachers anticipate their pupils' reactions, relied on three successively larger tests that we have called exploratory teaching, trial teaching, and field test.

The first, exploratory teaching (step 3), occurred very soon after a unit was invented and again whenever a unit was revised. It was carried out completely by project staff members functioning as "guest instructors" in elementary school classrooms or with smaller groups of children as in Montgomery's example given. Two to five members of the development team planned and participated in the exploratory teaching for one unit. They brought the necessary equipment, prototype student manual pages, and sometimes video or audio recording equipment. One of the staff members actually conducted the class while the others observed the sesssions, occasionally interviewing children concerning their ideas or questions.

After every exploratory session, one or more of the participating staff members prepared a written report in which the activity, the children's reactions, and the operation of the apparatus were described fully. These reports were filed and later served as raw material for the redesign of equipment, revision of the activity, and the preparation of teacher's guides. The activity was also discussed in a "post mortem" session in which every participant could express his/her views frankly.

The second classroom test, trial teaching (step 6), was carried out by regular teachers in the project's Berkeley area schools using trial edition teacher's guides, student manuals, and equipment kits. These classes were visited regularly by the unit's developers and also by other staff members who observed the teaching, occasionally spoke to children, and conferred with the teacher concerning any questions the teacher might have. Reports of the observations were filed after the visits and ultimately served as source material for revision of the unit. Individual conferences after school, feedback meetings, and feedback questionnaires enabled teachers to communicate their reactions to the developers. The used equipment was examined carefully for signs of wear or failure.

The field test stage of classroom teaching (step 11) was carried out in the five trial centers as well as in the Berkeley area. These teachers used the preliminary edition published by D. C. Heath and Company. Project staff observed the classes in Berkeley, while the coordinators and

Sixth-graders in an exploratory class conducted by Staff Physicist Marshall A. Montgomery compare the forces they can exert.

their assistants observed classes in the trial centers. Project staff also visited the trial centers, observed classes, and met with teachers two or three times a year. The coordinators submitted quarterly reports of their experiences in teacher education, classroom observations, suggestions from teachers, and specific comments concerning the teaching activities.

These classroom trials afforded the project three feedback loops through which curriculum ideas could be tested on an ever larger scale: first with one or two classes of children, then with ten teachers and about three hundred children, and finally with fifty teachers and more than one thousand children in six widely separated locations in the United States. The tests served somewhat different purposes.

Exploratory teaching helped to give the development team first-hand information about the children's reactions to the ideas, activities, and equipment in the unit. The time required by the children to complete certain tasks, the questions they asked, the preconceptions they revealed, their preferences regarding procedure, their ability to read student pages, and their level of interest could be assessed directly and taken into account both in the subsequent teaching program and in the preparation of the trial edition. The teacher's problems of equipment maintenance and storage did not arise.

During trial teaching, the next step, the development team secured a first response from teachers concerning the demands that teaching the unit placed on them. The pace of teaching was substantially slower when carried out by a regular teacher rather than a project staff member coming on a prearranged schedule. In addition to allotting shorter periods for science, the preparation of materials and cleanup had to be carried out in the classroom rather than in the project's laboratories. The teacher had to teach other subjects also, and therefore was not so carefully primed with respect to the science lesson. Sometimes illness, special school programs, or lessons in reading or mathematics preempted the time ordinarily assigned to science. The project learned that teachers would take about twice as long as the project staff to complete a unit--about four months if the exploratory teaching, on a twice-a-week schedule, had taken two months.

Other matters evaluated during the trial teaching were the clarity of the teaching suggestions, the adequacy of the equipment when not carefully managed and repaired by knowledgeable scientists, ideas for supplementary activities contributed by teachers, the usefulness of the student manual, and any teacher anxiety aroused by the activities.

The country-wide field test, finally, enabled the authors to sample the reactions from a large number of teachers of very diverse backgrounds to activities that were known to function reliably with children. The practicality of the equipment mass-produced under stringent cost limits, the clarity of the teacher's guides, the shipment of plants and animals over large distances and during all seasons, the program's maintenance requirements from year to year, and the requirements for teacher education were investigated. Additional valuable data came from early independent users of the SCIS program, such as Washington, D.C., Los Angeles, Cleveland, Mercer Island (Washington), Evanston (Illinois), Chicago, and several communities in Oklahoma. Because the trial centers were so important, we shall expand on their function in the next section.

The Trial Centers

The five SCIS trial centers rendered exceedingly valuable services to the project, first in regard to the field test and later in regard to implementation. Trial center operation began in 1966 and ended officially in 1971, after fifth-grade classes had used the SCIS program with support from the project in Berkeley for five years. Thanks to the adoption of the program by trial center communities and their own purchase of the remaining final edition units for the upper grades, many of the children nevertheless completed the entire six years of the SCIS program.

The purpose of the trial centers was outlined in the 1965 SCIS proposal to the National Science Foundation, where four distinct but complementary items were identified: (1) the larger group of teachers and children will test the reliability of teaching procedures and effectiveness of teacher's guides, student manuals, and laboratory materials; (2) preparation of the teachers will serve as pilot experience for the development of an inservice education program to accompany SCIS; (3) a sociological and psychological evaluation of the SCIS program will be carried out; (4) each of the cooperating institutions will make use of the trial center for its own educational activities. Looking back at the accomplishments in the trial centers after ten years, one can see clear contributions with respect to all but item 3, the evaluation, which had to be reduced drastically because of insufficient funds and the premature termination of the preliminary edition.

In the trial centers, the SCIS units were used in a very wide range of teaching situations: city, suburban, small town, and rural schools; self-contained classrooms, clustered groups, and ungraded primary grades. The pace of the teachers varied greatly, with the fastest proceeding through the program at twice the pace of the slowest. Some teachers added supplementary activities and encouraged their pupils' investigations so that one unit occupied almost the entire school year. Their first experience with a unit was a substantial learning experience for most teachers, whose second-year evaluations revealed their abilities to enrich the program, while they had used the teaching suggestions literally during the first year.

Reports from teachers, school system supervisors, principals, and trial center coordinators were most positive regarding the effectiveness of the program to involve the children and the teachers. The teachers also recognized the program's value for stimulating language development in the primary grades, a very important school function. One tangible evidence of the program's success was its installation in additional classes or additional schools with local support.

This response indicated that the SCIS curriculum materials in conjunction with suitable teacher education were indeed reliable for wide use far beyond the rather narrow conditions of the Berkeley area trial schools. It also showed that teaching the program was itself an educational experience for the teachers, some of whom reported a gradually increasing awareness of the inquiry-oriented approach over a period of several years. Other teachers responded to the program with immediate enthusiasm because it enabled them at last to teach in the way they had always hoped to deal with children.

At the same time there was frank though relatively minor criticism of some aspects of the program, and this very helpful information contributed to the revision of the units for the final edition.

For illustration, here are some of the specific comments regarding the preliminary edition of *Interaction and Systems:*

Chapter 2, "Picture Record" - Although the teachers liked the student manual pages 2 and 3, they did not work well with the children [sic]. The children did a number of experiments with the objects and, therefore, attempted to use several colored crayons with each page. By the time the child was finished with the page, including the making and the attempting to correct mistakes, the page was nearly useless to the child and to the teacher.

Chapter 3, "Invention of the Interaction Concept" - The interaction of bromothymol blue and vinegar seemed to steal the show. In using the roller skate and magnet, a better support should be provided for the magnet as it attaches to the roller skate.

Chapter 8, "Comparison of Pulley Systems" - Children need to be quite mature to care anything about ratios. The relation of the pulleys to everyday life should be explained. Most of the children could not use fractions.

Chapter 9, "Invention of Evidence of Interaction" - The children become so excited when the photographic paper and ozalid paper change colors that they miss the evidence of interaction concept.

Chapter 10, "Gathering Evidence Through Various Senses" - This chapter was rated very high by the teachers. It proved to arouse interest and individual investigations and was very thought-provoking. The teacher needs to stress the word "evidence" throughout.

Chapter 15, "Aluminum Foil and Copper Chloride Solution" - Are the labels necessary? Must each child have his own cup back? A great lesson! I strongly recommend that Chapters 12 and 15 be placed closer together.

Chapter 19, "Electrical Interaction" - An excellent lesson! The children love this activity and the teachers rate it consistently high. All clip leads should be replaced and be stronger.

Chapter 20, "Objects that Can Close a Circuit" - The children enjoyed the lesson but had difficulty with the term "closed circuit." The teachers questioned whether this term is necessary at the second grade level. The children are able to comprehend the concept and make the observations without any difficulty, but are confused by the term.

One can see that the comments deal with conceptual aspects, procedures, and equipment. Sometimes there were conflicting recommendations, with some teachers very satisfied by an activity while others requested changes. Then, of course, the revision team had to look for a compromise or disregard some advice.

Here are some of the larger changes in the program that resulted from the trial center feedback. First, the extensive scientific background information included at the beginning of the preliminary edition teacher's guides was eliminated; in its place, more limited and specific background information was included in each part of a unit, or sometimes at the beginning of a chapter. Second, the subject matter of the program was simplified by the reduced emphasis on comparison signs in *Material Objects*, on the anatomy of *Daphnia* in *Organisms*, on energy sources and controlled experimentation in *Subsystems and Variables*, and on reference frames in *Relative Position and Motion*.

Third, certain organisms shipments in the life science units were consolidated and resequenced, some organisms were replaced by more satisfactory ones (hydra by damsel fly larvae, duckweed by *Wolffia* in *Populations*), and still others were eliminated entirely (catfish, goldfish). Fourth, the equipment containers were made more sturdy and more spacious to facilitate the storage and re-use of permanent items. In addition, of course, the teacher's guides and student manuals were completely rewritten for greater clarity, teaching suggestions were improved, some completely new activities were introduced, and optional activities suggested by trial center teachers were added.

One of the objectives of the trial centers had been to assist in the educational programs of the sponsoring university. All five centers contributed to teacher education by affording student teachers opportunitites to observe the SCIS program in use and to teach science activities taken from the program. In addition, staff members and doctoral candidates carried out research projects that investigated problem solving, intellectual development, performance on standardized tests, language development, and scientific attitudes of students in the SCIS program. Teacher question-asking techniques and other aspects of an inquiry approach were also investigated (see Appendix H).

As final comment on the work of the trial centers, we point to their effectiveness in dissemination through teacher education, leadership training, and serving as a model with respect to innovative science teaching. This aspect is described further in Chapter 9.

Chapter 8 Evaluation

The evaluation studies carried out by the SCIS project served primarily to assess the impact of the program in such a way that the development teams and the teachers could choose better strategies for teaching. In other words, the staff was concerned with feedback loops.

Now, it is useful to distinguish two types of feedback loops. One included the SCIS project, the school, the teachers, and the pupils. The agency gathering the feedback information was the project staff, which had to modify the curriculum materials in the light of classroom experience.

The second feedback loop included the teacher and the pupils. The teacher had to be sensitive to the pupils' behavior and prepared to change classroom procedures in the light of their reactions. Thus both the teacher and the project needed diagnostic devices that were able to identify teaching difficulties and learning opportunities.

For the teacher, these feedback loops had to be permanently built into the curriculum. For the development project, the feedback loops had only temporary existence, until the publication of the final edition.

The Value System

The basic ingredients of evaluation are observation and judgment. Before proceeding further in this chapter, we shall deal with the value system within which the judgment is made. To establish a value system, curriculum makers can identify educational objectives, perhaps in behavioral terms. The students' average progress toward achieving these objectives then serves as a yardstick for retaining or revising an activity, pursuing teacher education with certain emphases, and/or taking other indicated steps.

The SCIS staff considered this procedure too limited because a teaching program has so many cognitive and affective aspects that a complete list of objectives could never be constructed. Still, some objectives may be appropriate, and their attainment can give a partial measure of an activity's effectiveness.

A second approach to defining a value system is through extensive discussion and collaboration among the members of the development team, until an implicit operating concensus is reached. The result of this process has been called a "platform": it is never described completely and explicitly, but rather represents an intuitive sharing of values. Stated most compactly, the SCIS program has the overall objective of helping students to improve their scientific literacy--a combination of basic science knowledge, investigative experience, and curiosity. The SCIS platform has been given partial expression in the teacher's guides, but it cannot be readily communicated to non-staff members and is likely to have residual ambiguities even for the members of the development teams. Nevertheless, the platform approach complements the objectives approach and has been of great value to SCIS.

Now we should like to add perspective to our account by a comment about educational objectives in general. Explicit performance objectives are intended to focus student behavior on the stated outcomes and permit rigorous evaluation with respect to these outcomes. If the public has preconceived ideas about the performance of students, then a school must direct its efforts along those lines. In elementary school arithmetic and reading, for instance, the public has very definite expectations, and the difficulties encountered by mathematics and reading programs that did not meet these expectations are well known.

As far as science is concerned, however, the public has at present no well-defined notions about what children should be learning in elementary school. There is no agreed-upon body of science facts or collection of science skills all children leaving elementary school are expected to possess, in the sense they are expected to be able to read and use arithmetic. To add variety to the educational program offered by a school, the SCIS project therefore considered it appropriate and desirable to encourage diverse teaching emphases in SCIS. The only requirement was that the children investigate problems and apparent contradictions which arise from observations and theories of natural phenomena.

In the SCIS program, therefore, educational objectives are included only with the parts of a teaching unit--about a month of instructional time--and not with individual activities or lessons. In addition, they are stated in general behavioral terms rather than very specifically. An example from *Populations* is, "To connect food chains to form food webs." Note that the scope of the food chains and the organisms involved are left unspecified, as are the reliability of a pupil's performance, the latency, and other details. The fact that this approach makes rigorous performance evaluation impossible is irrelevant, because the SCIS curriculum was developed for use in teaching on a large scale and not for research purposes.

Thus, schools and teachers were urged to develop their own objectives for using the SCIS program--objectives that might relate to science learning, language development, social outcomes, and/or other local concerns. Under these circumstances, explicit and detailed performance objectives would have preempted local decision making, while the more general objectives given served as helpful but not restrictive guidelines.

Formative Evaluation*

When describing the development process for the SCIS program in Chapter 7, we pointed out that it included repeated formative evaluation by the project staff. The value system for making the judgments in each instance was derived from the SCIS platform aimed at scientific literacy as described in the preceding section. Though the specific criteria varied somewhat from one step to the next, all were ultimately related to these three most important ones:

1. Intrinsic interest of the activity for children--do most children show spontaneity of involvement, curiosity about the outcome?

2. Reliability of the phenomenon--does blue BTB always change color after children blow into it for about twenty seconds? Do snails always turn away from the hottest rocks that can be prepared in the classroom?

3. Practicality in the classroom or other available space--can each child pursue his/her ideas as a member of a group within a limited working area, in spite of distractions provided by other children, and using equipment that can be maintained or replaced easily at low cost?

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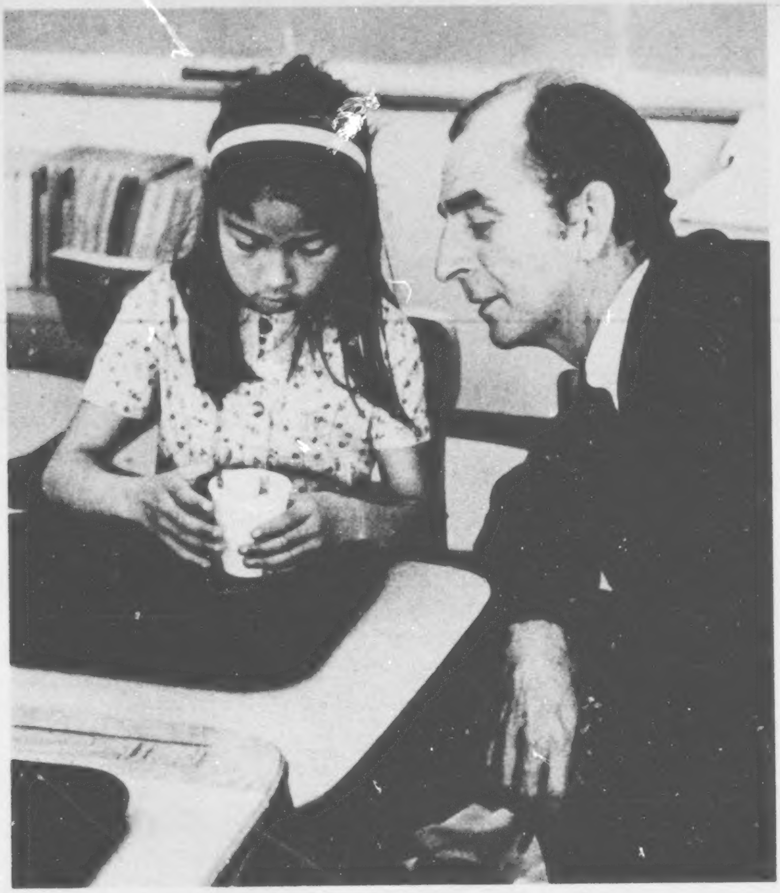
*Evaluation undertaken to gather feedback during program development is often called formative evaluation, while an assessment of a program's impact after completion is termed summative evaluation.



Formative evaluation is carried out by Coordinator James R. Eakin.

Unfortunately, these three criteria lead to certain conflicts. Thus, criterion #3 above tends to restrict what can be done in terms of #1 and #2. Beside cost considerations, one must also keep in mind the facilities in an elementary school classroom (perhaps no running water), the storage space, the time available for science, and the teacher's ability to be well informed about many differing experiments and pieces of apparatus. Arriving at the best compromise necessitated repeated testing--first in the laboratory and exploratory teaching to find whether criterion #2 was met, then in exploratory and trial teaching to find whether criterion #1 was met, and finally in the field test to find whether criterion #3 was met.

We have already explained that classroom observations by project staff members and trial center coordinators were the most important source of information for formative evaluation. Next came comments from the teachers, who met regularly with staff members while they were teaching a unit and provided additional information after the completion of teaching. The teachers' comments were organized according to the chapter of the unit, as in the example from *Interaction and Systems* feedback presented in Chapter 7.

A third contribution to formative evaluation was made by Pat Ness and Ellen Siegelman, two research psychologists on the project staff, who carried out a small-scale testing program of pupils in conjunction with trial teaching and field tests. Between 1965 and 1968, Ness, Siegelman, other staff members, and consultants prepared twenty-eight reports of evaluation studies they carried out. A complete listing is included in Appendix I.

The results of these investigations enabled the developers to assess the impact of the program in a manner that complemented the classroom observations. The pupil tests included individual problem-solving interviews, paper-and-pencil responses to tasks posed in conjunction with demonstrations, and group laboratory activities, which reached all children in a class or in a randomly selected sample. They were not biased in favor of the more assertive children who participated overtly in class activities and could be noticed easily by an observer.

To illustrate the nature of the reports, we shall quote passages from two of the references in Appendix I:

> *Very few children found it possible or necessary to use a single criterion for aliveness; the tendency was rather to introduce several, usually different ones for plants and animals. If aliveness is taught in connection with plant and animal distinction it would seem that there are fruitful possibilities for reinforcing that distinction on the basis of the way in which organisms appear to be alive. Perhaps some unitary criteria can be found for all living things, but in addition, differences (as well as similarities) could be pointed out between animal and plant growth or between animal and plant movement. One inventive child said, "Plants move too; they move when they're growing; they move very slowly."*

> *In general, these interviews suggest that the work on biotic potential could be strengthened; that the concept of generations needs to be distinguished from that of life cycles; and that the human animal should be brought into the pic-*

> *ture, in terms of (1) generations and the human life cycle, and (2) the human as animal. The unit might have even greater relevance for the children if they could see continuities, parallels, and differences between human and animal life cycles, or between the need to overproduce young in an organism that has little provision for care of the young and the reduced need to overproduce in the higher animals. These might be incorporated as ideas for the children to think and talk about. Other suggestions about the bases for the plant-animal distinction and for "aliveness" have already been mentioned in the text of this report.*
> (Ellen Siegelman, Life Cycles Feedback Testing, March, 1968)
>
> *The responses of SCIS children to Test 1 and to Question (b) of Test 2 show that they realized that a system's identity is changed if an object is added to or removed from the group, but that it is not changed if an object within the system is divided into smaller pieces. The results of Question (b) of Test 2 indicate further that students can itemize the components of a system when asked to do so, but that they have difficulty in choosing a system for a specific purpose. The answers to Questions (c) and (d) of Test 2 show that SCIS children who had studied the* Interaction *unit, and non-SCIS children who had not, gave the same description of changes occurring in an experiment.*
>
> *Many questions remain to be answered concerning the effect of these manuals, and further testing should be done in the 1966-67 school year and thereafter to assess the full effect of the manual. One might ask the following questions:*
>
> 1. *Do the children recognize a system of objects as a whole which has properties not possessed by its individual parts?*
> 2. *Do the children realize that a system may include segments of common objects?*
> 3. *Can the children include the same object in several systems at once?*
>
> (Patricia D. Ness, Systems, Interaction Evaluation, Spring, 1966)

A fourth contribution to formative evaluation was provided by studies of children and teachers, in and outside the classroom, to determine their attitudes, concerns, and interactions during the science classes more generally than in direct relation to concepts or tasks in the SCIS program. Consider, for instance, the following excerpt which concerns the trial edition of the upper grade physical science units *Phases of Matter* and *Energy:*

> *In the upper grades, many of the activities look to me like work. Materials may be novel in the beginning of the unit but the variation through the curriculum is not great. Since many of the activities have rather specific goals and methods, a child's performance can be evaluated by himself and others; he may do the experiment correctly or incorrectly, successfully or unsuccessfully. Children may, and often do, approach the materials as an opportunity for play, but playfulness leads in quite different directions from the goal-directedness required for systematic experimentation and observation. We may be impressed with the role of playfulness in the scientific enterprise without forgetting that this playfulness is in the context of discipline, commitment, and purpose. You may hope that the fifth grader has fun in carrying out an experiment, but you are banking on his also taking seriously the questions and methods of the science unit. The procedures and results of the experiments cannot have their intended meaning to the student if he does not see the procedures as means of answering his own questions. Furthermore, I don't think anyone would argue that everything the student is supposed to do in an activity will be fun. For the student to be interested in doing the less entertaining parts of an activity requires that he identify with the purposes of the experiment. This is a quite different type of involvement than is being asked of younger children.*
> (Donald L. Flory, "Dynamics of Classroom Behavior: an Informal Study of SCIS" in What is Curriculum Evaluation? Six Answers, compiled and edited by Robert Karplus, December 1968)

How the actual teaching of a unit may educate a teacher is revealed by the following report:

> *As far as the first-grade program was concerned, there was unanimous, overwhelming agreement that the* Organisms *unit (D. C. Heath, 1968) generated the most eagerness, interest, and curiosity...Even those teachers who had previously stressed good deportment and silence in their classrooms just let the children "go." The atmosphere in the first-grade classes was electric with excitement that first day of the children's introduction to* Organisms.

> *Furthermore, the teachers appeared to have little difficulty with the ad-hoc nature of this program. It was interesting to me to observe that some teachers' rigidities and possessiveness of materials, which had been manifest for the most part during the earlier periods of* Material Objects *(D. C. Heath, 1966), just about disappeared with the* Organisms *unit...*
>
> *The teachers at first manifested an almost complete lack of awareness regarding their own behaviors in the classroom. Changes in attitudes occurred as they gained more awareness of themselves and learned to examine their role in the classroom. Many of the poor teaching practices which I have described appeared to be derived from the teachers' misconception of their role. Many of the teachers expressed surprise at themselves and at the burdens which they took on as teachers once they began to perceive themselves as their students might...They, like many other people in our society, seemed to fear freedom; they equated it to a loss of control. Even those teachers who had been the most rigid and repressive in maintaining their control over the classroom yielded in these attitudes and tried new approaches with the children when they realized that by so doing they could still have control of the classrooms.* (Olympia D. Tresmontan, "SCIS in the Classroom - A Sample" in What is Curriculum Evaluation? Six Answers, compiled and edited by Robert Karplus, December 1968)

The reports of the work falling into the fourth category of formative evaluation are included in Appendix I. In response to these comments, the staff examined the style of the teacher's guides as well as the organization of activities and incorporated the recommendations as extensively as possible. Besides influencing the revision of the units, these more general studies suggested areas of importance for inservice education of teachers. This subject is described in Chapter 9.

Evaluation by the Teacher

At the beginning of this chapter we referred to the feedback loops consisting of the teacher and pupils in the classroom. The teacher responds, both consciously and unconsciously, to the children's behaviors by adjusting the teaching in accordance with his observations and his perception of the aims of the program.

Because it is so rich in activities that draw on the children's spontaneity and involvement, the SCIS program gives the teacher many opportunities to make observations. In fact, an important role for teachers is to listen carefully to what the children say and to watch what they do, so as to capitalize on their ideas for extending an activity. The teacher education component of SCIS emphasizes this aspect of the teacher's role. Such continuous, informal evaluation is an essential part of teaching and is, as we pointed out earlier, built into the curriculum.

There are occasions, however, when the teacher needs more specific information regarding the children's understanding of a new concept--especially just after an "invention" activity (see Chapter 6). The teacher's guide may therefore include a "feedback activity" so designated in the teaching suggestions. Here is an example from *Relative Position and Motion*, page 54:

> *As another feedback activity, hold a Mr. O facing your pupils and tell them that he wants to report that they move up and down. After you ask them to stop, turn the Mr. O figure to face you and slowly move it up and down about 1 foot in front of you. Invite children to describe Mr.O's report of your motion; if necessary, explain that he reports that you move up and down. Then challenge the children to manipulate Mr. O in such a way that he reports that they are carrying out an impressive stunt even though they do not move. For example, Mr. O might report that they turn upside down, go over his head, or spin around him.*

In addition the teacher's guides include feedback activities in which children respond to a task in writing. Then the teacher can examine the work of each individual child, something that is difficult to do in a group discussion.

With all of these opportunities to assess a child's understanding, interest, and critical thinking, few teachers have expressed a need for more evaluation activities. They have, however, expressed a desire for more explicitly spelled out objectives that would help them guide the teaching program along productive lines. This was the one major item of feedback from the field test to which the project did not respond directly, because the authors were concerned that numerous detailed objectives might overly limit and/or direct the teachers' efforts.

Evaluation Supplements

Even though teachers did not express a desire for a more formal evaluation program, school administrators overwhelmingly requested one. The reasons for this interest seemed to stem more from the tradition of having a special evaluation program than from a genuine desire to know what was happening in the science classes. In its efforts to respond to this desire, the project staff, led by science educator Rita W. Peterson, proceeded cautiously. Innovative approaches were needed to permit assessment of some of the less tangible outcomes of the SCIS program as well as the children's understanding of various science concepts. At the same time, Peterson desired to avoid any temptation of "teaching for the test" or of inadvertently placing the teacher in a straightjacket that would reduce the spontaneity and variety of investigations.

By the spring of 1971, Peterson had proposed a multiphasic approach that was to include student perception of the classroom environment, process/content objectives, attitudes in science, general intellectual development, and teacher self-evaluation. In addition to the evaluation activities, charts for recording the evaluation outcomes were provided. Drafts for multiphasic *Life Cycles* and *Interaction and Systems* evaluation supplements were circulated to about forty science educators including the trial center coordinators, implementation leaders, and others familiar with the SCIS program. Their general approval included recommendations to reduce the supplements drastically. As a result, the first three phases only were retained, with material on intellectual development and teacher self-evaluation to be included in the *SCIS Teacher's Handbook*.

The formative evaluation of the supplements relied on classroom tests of individual activities and then a field test in the former trial centers and other communities that had adopted the SCIS program. Most teachers found the evaluation supplements acceptable, but none were enthusiastic. Very few teachers saw a real use for the supplements since they perceived themselves as evaluating their students' activities individually and continuously while they were teaching the program. In fact, the most positive reactions to the supplements came from teachers who had converted them into supplementary learning activities! The principal objections to the increased emphasis on evaluation were the time taken away from science teaching, the additional preparation required, and the recommended record keeping.

A fair appraisal of the evaluation supplements at this time is that they filled an administrative need but are not included extensively when the SCIS program is implemented.

Chapter 9 Diffusion and Implementation Strategies

What impels school systems and teachers to introduce new teaching procedures and new curricula? Central to innovation in education is surely the educator's sense of professional satisfaction and improved service to children and the community. Yet one must also consider the availability of resources: tested curriculum materials that allow all teachers--not just the most creative--to enrich their programs, teacher education activities needed to orient the staff, money to purchase the materials, and logistic support to maintain equipment from year to year.

Diffusion of the SCIS program, an innovative resource for teachers, has been accomplished through a combination of many efforts. One of these was the creation of awareness of the program through the SCIS Newsletter, journal articles, and teachers' convention programs (see Appendix J). Others were the development of leadership personnel, the creation of books and films for teacher education, the services of the five trial centers, publisher-sponsored workshops, and the conscientious efforts of the publisher's field representatives. The overall strategy of implementation was formulated by SCIS Assistant Director Herbert D. Thier, who called the approach an internalization strategy because it depends on leadership coming from the schools themselves and not from the project.

In this chapter we shall describe the strategy, the leadership training carried out at project headquarters in the Lawrence Hall of Science, Berkeley, the publisher's contribution to implementation (as distinct from ordinary promotion and marketing), and the approaches to teacher education developed by the many users of the SCIS program. Annual kit and replacement sales reflecting the impact of this strategy are given in Appendix K.

The Internalization Strategy

The main objective of this approach is to provide a strong local base of support for the growth and continued use of the SCIS program. Local interest must grow until a point is reached where a leadership team can be designated and trained to plan the implementation and carry it out. Then the team members obtain the necessary funds, make provisions for teacher training, and identify themselves intellectually and operationally with the SCIS program.

To be successful, the leadership team needs experience in the philosophy, approach, and operation of the SCIS program so its members can become "informed sources." Ideally, this experience can be acquired best through a close working relationship with the SCIS program developers, trial center coordinators, or science educators with very extensive implementation experience themselves.

Furthermore, the community needs to become familiar with the SCIS program on a small scale before making plans and commitments for large-scale introduction of the materials. Hence pilot schools are identified, pilot teachers are trained, and pilot classes are provided with the SCIS kits to give the program a trial in the school system. The effects of the program on the learning needs and capabilities of pupils can thus be observed. In addition, evidence will accumulate concerning the relationship of the new program to other parts of the school's instructional program. The information obtained during such a trial should be a major factor in deciding whether to proceed to a large-scale implementation of the program in the school system.

Once the community decides to proceed with full-scale implementation, leadership team members present the needed inservice courses with the assistance of some of the pilot teachers. After the training, the leadership team serves as consultative resource for the teachers. Finally, the leadership team cooperates with principals and other administrators to establish the necessary facilities for maintaining the curriculum materials from year to year. These facilities may take the form of an instructional materials center that serves many schools, or they may be decentralized on a school-by-school basis, with a teacher taking responsibility for coordinating supply needs and distributing replacements in the building.

The implementation process we have described is somewhat idealized and does not always occur in precisely this way. Often the implementation "team" consists of one informed source who later recruits associates to share the planning and work. The large-scale adoption may proceed by stages, with the primary grades participating during the first year, the upper grades during the second.

The value of the internalization strategy is its use of experienced personnel in Berkeley or elsewhere to allow the local system to increase the expertise of its own professional staff. In this way it avoids the all-too-common occurrence of a new program being introduced into a school system solely by outside consultants or experts with special grant funds, only to disappear when the grant expires or the experts leave the scene. Through internalization one can also achieve the large multiplier effect that originators of any new program must have if their work is to be widely influential.

The SCIS Implementation Program

Since 1967, when the preliminary edition was entering its second year, the SCIS project has operated an implementation program, as required by the internalization strategy. This program, directed by Jack Fishleder, uses study-visits to project headquarters in Berkeley to train individuals and teams capable of offering leadership in elementary science education. The objective is to produce informed sources who will, in turn, train teachers and school administrators to use the SCIS materials in their communities through pre- and inservice education, consultation with school administrators, and talks with parents.

It is expected that the participants will identify with the philosophy and approach of SCIS and other inquiry-oriented programs. The informed sources will recognize the following major aspects of change in elementary school science:

1. the evolution of a sequential, articulated elementary school science program based upon the structure of science as seen by scientists today;
2. the conversion of the elementary school classroom to a science laboratory in which the children can gain firsthand experience with natural phenomena;
3. the changing of the teacher's role from an unquestioned authority (who tells the child what he should know) to an individual who assists the child in conducting investigations and developing understandings;
4. the recognition of the learning process whereby a child progresses from thinking in concrete terms to thinking in abstract terms.

Since the implementation program is intended to provide an individualized exposure to SCIS, it involves five or fewer participants at any one time. It takes place primarily during the academic year when classes using the SCIS materials in the Berkeley area can be visited. The usual duration of the study-visits to Berkeley is one week. The visitor is expected to provide for his own travel, with the project contributing to the living expenses for five days.

The activities during the study-visit include formal and informal interaction with SCIS staff members, several visits to regular classrooms in urban and suburban schools using the SCIS program, review of the teacher's guides and equipment kits in a special workroom kept for this purpose, viewing of SCIS teacher education films, and extensive informal discussions with the other study-visitors. The program also acquaints the visitors with specific techniques for working with teachers to help them

Implementation Program Leader Jack Fishleder (right) and study-visitors attend a science class.

change their role, for estimating materials needs, and for obtaining partial outside financial support to implement the program.

Informality and flexibility are vital characteristics of the study-visits which provide a model for the SCIS classroom. It is very important that the study-visitors be at ease with Fishleder and one another, because only by expressing their thoughts, reservations, and concerns frankly will they be able to adapt to the role of innovator which is new for many of them. After observing various teaching styles and forms of classroom organization, they have to probe the advantages and disadvantages of each, and identify the teacher characteristics that lead to success. When studying a teacher's guide or viewing a teacher education film, they have to question the background in pedagogy, psychology, or science. Even though many of their questions do not have simple answers, the visitors have to feel sufficiently comfortable to raise the issues that trouble them. Only then can they formulate their own views independently of those of their colleagues or of SCIS staff members.

To make up a schedule, each visitor is asked to identify the major needs that led to the visit in the first place. Most responses to this question can be placed in these categories: get to know the SCIS units, meet and talk to staff people, understand the SCIS conceptual framework better, talk to school administrators and/or teachers using the program, study the teacher education materials and preview the films, try out some of the children's experiments, find out how to offer short teacher workshops, get ideas for pre- and inservice courses in science education, learn about materials supply and organisms culturing, gain practice in formulating implementation plans and soliciting outside support, find out about SCIS evaluation activities, and get acquainted with other new programs at the Lawrence Hall of Science. Some visitors have special interests that take them to other academic departments at the University of California and/or to other institutions in the Bay Area.

The informality of the first day, which usually includes hands-on science activities from a unit in addition to schedule-planning and getting acquainted with facilities, sets the tone for the rest of the week. Directness, frank presentation of views, discussion and, when necessary, disagreement characterize the exchanges of ideas. A disregard for status and rank of participant or staff member, a hard look at both strengths and weaknesses of the new science curricula, some risk-taking with others in the group, and the understanding that each individual will withhold judgment until the end of the week, all contribute to the value of the experience.

At the end of the study-visit, the individual or team feels knowledgeable and confident enough to provide leadership for the implementation effort in the home community. Working relations wih the Implementation Program at the Lawrence Hall of Science do not terminate with the visitors' departure, however. Mailings of SCIS newsletters and other project publications, gatherings at National Science Teachers Association conventions, correspondence with Fishleder regarding an implementation plan, site-visits by Fishleder or other SCIS staff members, and exchange of new ideas for teacher education keep several hundred past visitors up to date with new materials from the SCIS program and other science education projects at the Hall.

During the eight years of operation of the Implementation Program, almost 800 visitors have participated. Here is a summary of the annual number according to the kind of position held in science education:

Year	Scientists	Science Educators	School Administrators, Supervisors, etc.	Teacher Leaders	Total
1967-68	5	19	26	12	62
1968-69	3	23	17	6	49
1969-70	17	56	45	10	128
1970-71	19	47	41	13	120
1971-72	7	49	51	4	111
1972-73	17	38	43	12	110
1973-74	12	31	50	12	105
1974-75	9	28	49	14	105
Totals	89	291	322	83	790

We should add that during this time a substantial number of SCIS-based leadership training programs have been conducted outside Berkeley. Some of these involved twenty to forty science educators who attended National Science Foundation supported Resource Personnel Workshops for two to four weeks during the summer. New York Trial Center Coordinator Mary Budd Rowe helped develop this approach by co-directing the first such project at the University of

Texas in 1967. Both Teacher's College and Michigan State University later offered such workshops in conjunction with their trial centers and direct National Science Foundation support.

Two efforts that deserve special mention were partially supported through the SCIS project on a year-round basis for implementation of the SCIS program in rural and urban schools. The two were located at Michigan State University, East Lansing (1969-1971) and Temple University, Philadelphia (1970-71). They offered workshops for leadership personnel in their area through activities modeled on the program in Berkeley and served as prototypes for publisher-sponsored activities since 1971 (see below).

As illustrations of the impact of the internalization strategy we mention a few particularly noteworthy implementation efforts that have been carried out by former study-visitors. In 1971, the Division of Science Education for the State of North Carolina chose the SCIS program to help upgrade the quality of science instruction in the elementary grades. Study-visits by Paul Taylor and Max Walser of the Division led to four inservice workshops for 144 teachers and 22 other personnel. Further workshops in later years swelled the total number of trained teachers to more than 1,000. In addition, sixteen college professors participated in the North Carolina workshops, so that they were then able to include presentations of SCIS in their preservice courses. The student teachers' practice teaching in schools using the SCIS program also helped give them a good introduction to the program.

A second example is furnished by Francis P. Collea, Professor of Physical Science at California State University at Fullerton. His study-visit in 1971 led to National Science Foundation funded teacher training projects in Fountain Valley and other Southern California communities for the next four years. Collea has also offered two leadership training programs, university extension courses for teachers, and other service projects in Orange and San Diego counties. Fountain Valley classes were used in the development of the evaluation supplements and later field tested the trial edition of the supplements. Collea has continued his interaction with the Implementation Program and has also collaborated with Director Karplus and Assistant Director Thier on new, innovative projects in science education.

For another example of the influence of the Implementation Program, we turn to the direct help it gave to the University of Wyoming's National Science Foundation supported Comprehensive Program for Improving Science Education in Eight Western States. Two members of the University of Wyoming physics department, as well as six leadership people in their Portal School Program, participated in the Implementation Program. The introduction of SCIS in Denver, Cheyenne, Laramie, and many small rural districts in the west can be traced back to the Portal School Program of the University of Wyoming.

The successful implementation of the SCIS curriculum in the Bureau of Indian Affairs schools in the Arizona Indian reservations had its beginnings in the study-visits of Bureau leadership personnel in November, 1970. Further assistance was obtained from special inservice courses offered to Bureau of Indian Affairs teachers on the Arizona State University campus. This work with the Bureau has been extended to New Mexico and Alaska.

We could continue with examples of this kind from almost every state in the nation. The ingenuity of the study-visitors together with the genuine practicality and value of the SCIS teaching materials have contributed to the joy and excitement in science found by hundreds of thousands of elementary school children. The sales of new kits and of replacement materials to maintain kits (Appendix K) gives one measure of the SCIS program's acceptance by the public.

The reader may wonder how a one-week study-visit can really have a substantial influence on mature persons. The SCIS staff has also asked this question in the hope of strengthening the program, but has not been successful in providing a clearcut answer. It appears that five major factors combine:

1. The study visitor is preselected for his willingness to invest time and funds to make the visit.
2. The individually-tailored program emphasizes the professional and intellectual challenge of participating in an innovative effort in the company of thoughtful and able people.
3. There is no "hard sell" of the SCIS materials; instead, the problems of curriculum development are discussed frankly; differences of opinion regarding the compromises made in SCIS are expressed openly.
4. The personal qualities of the Implementation Program leader, who was able to concentrate on this activity since its inception, help

allay any anxieties the visitors might have at the beginning and allow them to see the potential of the SCIS curriculum for elementary school science.

5. The hands-on activities with curriculum and teacher education materials provide a core of essential information which a visitor can extend while he carries out an implementation plan.

Before concluding this section, we should add that the collaboration with the five trial center coordinators was, in fact, the very first leadership development activity undertaken by the SCIS project. In addition to conducting the field test described in Chapter 7, the five trial centers were active in teacher education in their regions.

All five trial centers conducted inservice courses, either with support from the National Science Foundation's Cooperative College-School Science Program, or as part of ongoing teacher preparation offerings. The University of Oklahoma's efforts were the earliest of these and served as models for projects that came later. Directly or indirectly they influenced science teaching throughout Oklahoma and in adjacent parts of Arkansas.

The University of California at Los Angeles undertook the largest programs, reaching more than 400 teachers over a period of several years. Teachers College, Columbia University, tackled the problems of urban ghettos through courses directed at the teachers of the nearby Harlem schools. The University of Hawaii covered the largest geographical area, with activities in United States Trust Territorries and Japan. Michigan State University offered National Science Foundation supported projects for the greatest number of years, reaching many communities in the central Michigan region.

The Publisher's Program

Rand McNally and Company, publisher of the final edition of the SCIS program, has augmented a publisher's usual promotion and marketing activities. With the help of an advisory committee of three members--one from Rand McNally, one from the kit manufacturer, American Science and Engineering, Inc., and one from the SCIS staff--funds averaging more than $100,000 annually have been used to (1) create awareness of SCIS through regional workshops, and (2) assist schools in using the SCIS program through teacher orientation sessions.

From 1970 to 1972, the early years of the SCIS final edition, Rand McNally engaged national science consultants William F. Labahn and Wandell Messinger, who attended the Berkeley study-visit program for their orientation. They then traveled about the country presenting the SCIS materials, background information, implementation plans, and inservice workshops to major school systems, state departments of education, and regional teacher groups. Selected school systems were helped in their implementation efforts through inservice programs for which Rand supplied leadership and materials. More than 20,000 persons attended about 600 sessions led by one of the science consultants or an SCIS informed source during these three years.

In early 1973, when the complete six-year SCIS program became available, consultant Labahn and the publisher's advisory committee determined that the needs of program users at the school district level had become more important and could be met better through permanent regional SCIS resource centers. The Michigan State and Temple University centers had enjoyed partial support from Rand during the preceding years and had served as models for this expanded center program. Now that the SCIS trial centers were being phased out because their field test function had been accomplished, the new resource centers furnished the implementation services that the trial centers had gradually come to provide as the program became better known.

The resource centers have given opportunities for interested individuals to examine the SCIS curriculum materials and work with equipment, guides, and films, as well as seeing the program in action in local classrooms. Furthermore, personnel associated with each center has conducted information and inservice workshops in its geographic region. Rand McNally has provided a complete set of kits, manuals, informational and promotional literature, teacher education films, and financial support for the center staff. Center support is awarded on the basis of proposals evaluated by a special screening committee. From five centers in 1973, the number has grown to twelve in 1974 and seventeen in 1975. All centers are listed in Appendix L.

At the time the resource centers were established, assistance to school districts by former study-visitors largely replaced training and orientation sessions conducted by Rand McNally's national science consultants. Some of these informed sources have worked through the resource centers while others, in parts of the country not reached by the centers, have worked individually with school districts.

Rand McNally has aided teacher education in many other ways. In 1970, a sample teacher's guide with selections from several units was published to provide information about the variety of activities included in the program. Sample equipment kits with laboratory materials from several units were assembled for the same reason and serve to allow hands-on activities by teachers attending small workshops. The SCIS teacher education films have been purchased from the project and circulated without charge to inservice programs, as have supplies of laboratory materials. Rand has conducted two leadership training workshops of its own to increase the number of informed sources and up-date the knowledge of leadership personnel who had participated in training programs before the program had been completely published. Finally, the publisher has supported the expenses of study-visitors to the Berkeley program since 1973.

The increasing number of knowledgeable local leadership persons and the establishment of the resource centers have decreased the need for the national science consultants working full time for the publisher. As a result, the new position of product manager was created to supervise and coordinate all the implementation activities we have described. Currently the product manager is Fred Gebarowski.

In concluding this section, we should like to acknowledge the very valuable services supporting teacher education and implementation being provided by many of Rand's field representatives. Though their major responsibility is assisting school systems in purchasing the SCIS curriculum materials, they must also provide information regarding the rather complicated supply and maintenance requirements of the program. They additionally help to identify instructors for inservice sessions, deliver sample materials to the site, and otherwise cope with many logistic problems that are encountered in a laboratory-based program for schools that are basically not built to serve as laboratories. Many teachers and children have benefited from the contributions of the field representatives, whose vital role must not be forgotten.

Teacher Education

One of the very important elements of educational innovation is teacher education. When describing the internalization strategy earlier in this chapter, we referred to the establishment of a classroom laboratory and changing the role of the teacher from authority to facilitator. How was teacher education accomplished in the SCIS program?

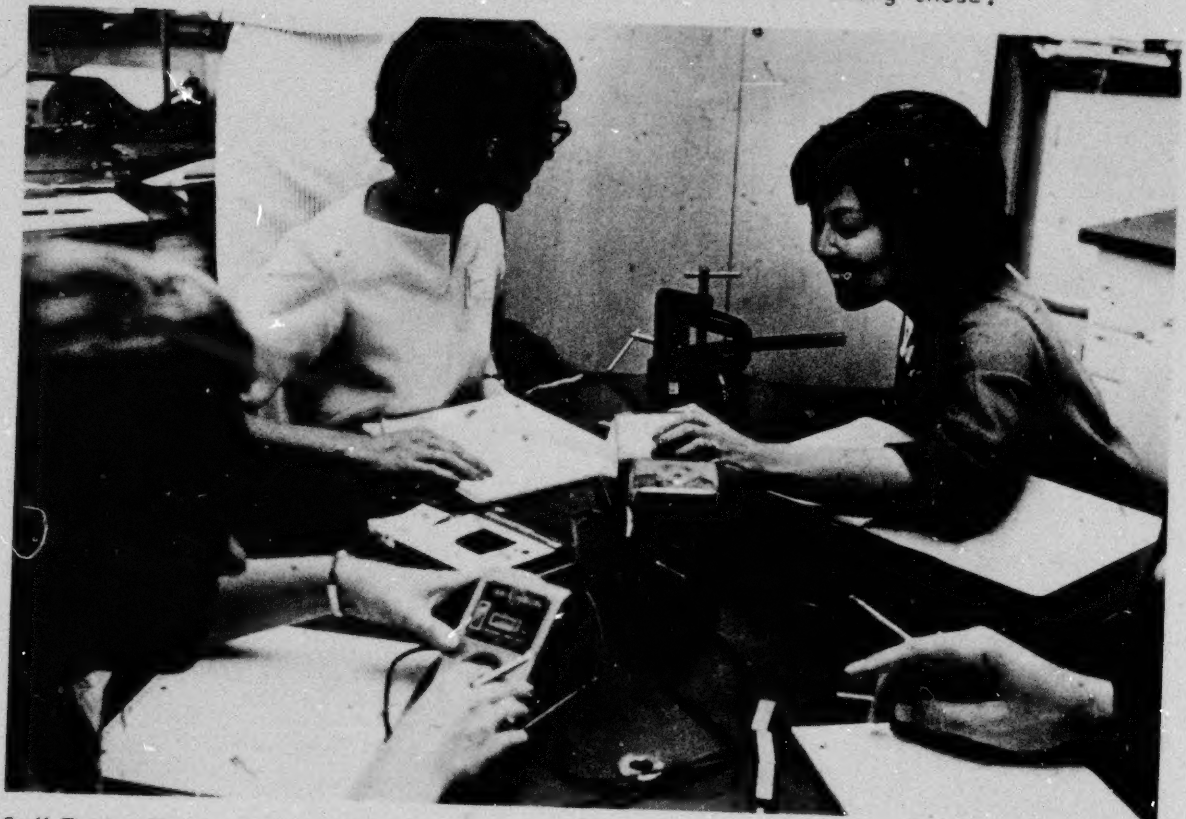
The two principal means of teacher education have been the teacher's guides and the participation in special inservice or preservice courses. Four goals have to be achieved in varying degrees with different teachers: (1) adoption of a child-centered, inquiry-oriented classroom environment, (2) familiarity with the science phenomena and laboratory materials in the units to be used, (3) understanding of children's intellectual development, and (4) acquaintance with the nature of science and its logical and conceptual structure.

The teacher's guides concentrate on the first two of these four items, since these are primary in the day-to-day operation of the program in the classroom. The guides are written in simple and direct terms to encourage teachers to use the program even if they are not well prepared to do so. The guides also help teachers gradually modify their teaching techniques in the light of feedback from their pupils. In particular, the eagerness and interest of the children engaging in science activities are a significant teacher education tool. Thus, the regular use of the SCIS materials provides an ongoing teacher education experience.

Pre- and inservice courses can be concerned with deeper and longer range matters than the successive science activities, although these must receive substantial attention. All four of the goals we have mentioned are therefore built into materials developed primarily for teacher education. These include the *SCIS Teacher's Handbook* with background information relating to all four goals, documentary films (completely unrehearsed) of classroom activities using the SCIS units, and an *SCIS Omnibus* with reprints of articles published by SCIS staff and collaborators during the development process.

In the internalization strategy of implementation, these teacher education materials are resources for local leaders who plan and conduct the teacher education courses. The project has not developed a "formula" approach to teacher education, just as there is no formula for teaching the SCIS units. Accordingly, there are widely differing teacher education courses being taught in various communities that are introducing the SCIS program. All of them, however, devote themselves to the four goals listed above.

Adoption of an inquiry-oriented classroom environment requires extensive changes in the teaching style of many teachers. These occur only as a result of social experience involving leadership personnel, other teachers, and children. Actually working with children in one-to-one or small group situations is therefore an important part of successful courses. Because most people have great difficulty in perceiving themselves the way others do, the videotape recorder has become a very important tool in teacher education, by means of which a teaching session can be captured for instant replay. It allows an individual to review his acts and words in the company of a colleague or teacher who can raise questions about the children's behavior, the teacher's procedures or questions, and interactions among these.



Staff Teacher Christina K. Kageyama conducts a teacher workshop.

Laboratory investigations using the equipment in the kits are a second common element of SCIS teacher education programs. Since few teachers have a strong science background, most have never looked at *Daphnia* through a magnifier, seen schlieren as salt or copper chloride dissolves in water, or observed the systematic changes in distance traversed by a projectile (rubber stopper) aimed at various angles relative to the horizontal.

Inventing new ways of using the equipment, asking their own questions, and making their own observations for sharing with colleagues who have done similar things help to prepare the teacher for working with children who will be engaged in similar activities. Even hearing their instructor admit that he does not know the answers to some questions makes it easier for the teacher to do the same thing with pupils.

Beyond these two common elements, teacher education courses diverge widely with respect to the emphasis placed on science learnings, psychological understandings, equipment management skills, and culturing of living organisms. It would, of course, be very helpful to address all these other matters, but time limits rarely permit that. Instead, the instructor has to make choices of what will be included and what will be left for the teachers to work out while they are using the program in their classrooms. If teachers actually open their kits and distribute the materials, their pupils will teach them a great deal. What the instructor must prevent is a kit's remaining unopened and unused.

In concluding this section, we must mention that the SCIS program and other innovative science curricula are described in varying detail in most new science education texts that are being published for use in teacher education programs. As might be expected, texts by Herbert D. Thier, John W. Renner, or other authors who have been associated with an innovative science program give great emphasis to the inquiry approach. To the extent to which these texts are used in preservice education, they will prepare more teachers for inquiry-oriented teaching in the future.

Implementation Outside the United States

Because the SCIS program is used with young children, the SCIS staff has always had reservations about the uncritical acceptance of the curriculum by schools that serve in a different socio-cultural environment. While the scientific conceptual framework is universally valid at the present time, the children's preconceptions and intellectual growth vary from country to country. The activities and materials that are interesting for children are therefore likely to be different in the United States, South America, Africa, and Asia. Adaptation rather than translation proved to be a more promising road for exploiting the worldwide potential usefulness of the SCIS program.

One faithful translation with only minor adaptation has been prepared by the Institut de Recherches Psychologiques, Inc., under the leadership of Jean-Marc Chevrier for use by French-speaking children in Canada. The similarity of the Canadian and United States environment for children made this an appropriate procedure.

Elsewhere, adaptation has been the usual procedure. In Sweden, Denmark, Hungary, Italy, and the United States Trust Territories in the Pacific, complete science curricula for elementary schools are being developed with the conceptual framework and hands-on orientation of SCIS, but using activities more appropriate to the country or region. In Korea, Taiwan, Brazil, Israel, the Philippines, and Malaysia, SCIS has had considerable influence on current thinking with respect to elementary school science.

Looking Ahead

During the 1950's, science teaching in the elementary schools was largely based on textbooks when it was not omitted entirely. At that time, about $5,000,000 was spent annually on science equipment. In 1975, elementary schools spent about $10,000,000 for inquiry science programs, used by about 5,000,000 children--fifteen percent of all elementary school pupils. Does this give evidence of a real increase in laboratory science when corrected for the effects of inflation, total enrollment growth, and other demands on the school budget? We should like to believe it does, but cannot claim a very sound basis for our conclusion.

At the same time, we wonder what the future holds. The National Science Foundation's massive support for the development of new science curricula appears to have ended--and perhaps the community of science educators has temporarily exhausted its innovative ideas. Further implementation of the new programs is the principal current agenda item.

Has the inquiry approach been accepted in the sense that schools will gradually increase their use of hands-on laboratory experiences for children and decrease their reliance on the learning of facts? No one knows exactly what preponderance of leadership people must be committed to inquiry science to bring about a permanent change in the schools of our country. The built-in inertia of the American school system seems to require a still greater penetration of innovative programs before one can say they have become internalized and will be maintained in the face of turnover of teachers, school administrators, and school board personnel.

One factor that is sometimes overlooked is that the new programs like SCIS are not meant to be "ultimate" programs. They allow teachers and children to expand and change their curriculum, and will themselves evolve and change in the future. The direction for change that they define, however, is a distinct break from the science education customary in the preceding decades. Expectations that commercial publishers will forcefully carry the message of inquiry-oriented science programs are unrealistic at present. Publishers serve the market and therefore reflect a concensus of what is currently acceptable. Professional institutions in science education such as the Lawrence Hall of Science and leading teacher training schools must continue their efforts to provide leadership for publishers, science educators, teachers, and children.

Appendices

Appendix A National Science Foundation Support, 1961-1977

Award Year	Award Amount
1961	$ 25,000
1962	40,650
1963	99,480
1964	229,300
1965	1,052,000
1967	176,000
1968	1,260,000
1969	1,171,000
1971	138,455
1972	160,000
1974	74,800*
1975	100,000*
Total authorized	$4,526,685

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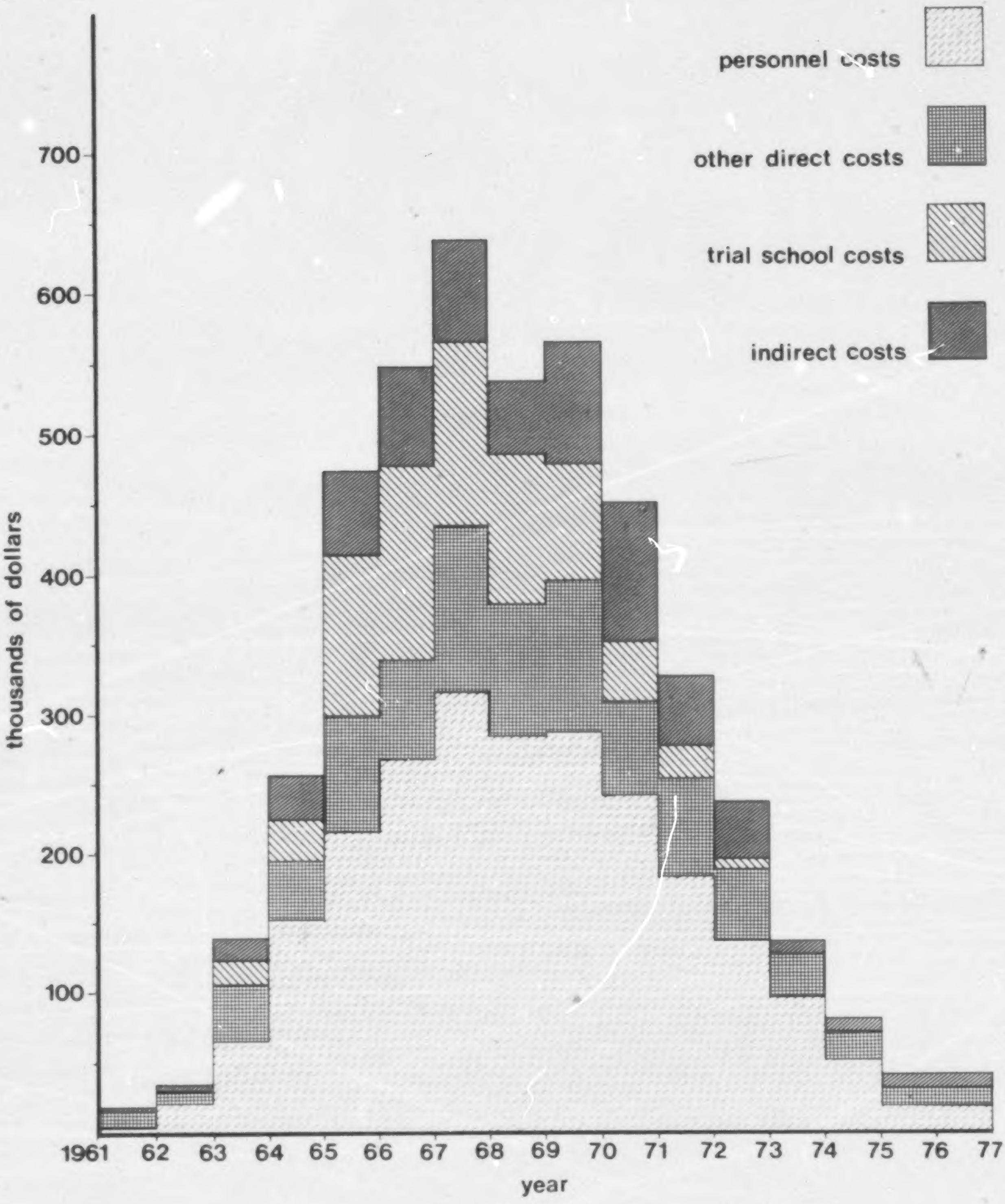
*Application of royalty income to the purposes of the grant and management of the materials produced with grant support.

Appendix B SCIS Project Expenditures, 1961-1977



Appendix C SCIS Advisory Committee Members, 1964-1975

Professor J. Myron Atkin, Education, University of Illinois, 1969-1975

Professor Howard Bern, Zoology, University of California, Berkeley, 1964-1975

Professor Lee Cronbach, Educational Psychology, Stanford University, 1967-1975

Professor Richard S. Crutchfield, Psychology, University of California, Berkeley, 1964-1975

Professor A. Wells Foshay, Education, Teachers College, Columbia University, 1963-1975

Professor John I. Goodlad, Education, University of California, Los Angeles, 1963-1975

Sister M. Jacqueline, Vice-President, Webster College, 1963-1967

Professor John L. Kelley, Mathematics, University of California, Berkeley, 1964-1975

Professor Polykarp Kusch, Physics, Columbia University, 1964-1975

Professor Alan Portis, Physics, University of California, Berkeley, 1969-1975

Professor Lee Preston, Business Administration, University of California, Berkeley, 1969-1971

Professor Laurence Strong, Chemistry, Earlham College, 1964-1975

Professor Harold Weaver, Astronomy, University of California, Berkeley, 1964-1969

Appendix D SCIS Staff Members and Consultants, 1961-1975

Norman Adler, Consultant, 1965

Leslie R. Allen, Acting Coordinator, Hawaii Trial Center, 1967-68, Staff Assistant, 1967-72

Millie Almy, Consultant, 1965

Elaine Amoruso, Secretary, 1964

Steven M. Barnes, Staff Assistant, Michigan Trial Center, 1968-69

Guilford H. Bartlett, Jr., Staff Assistant, New York Trial Center, 1966-68

Marilyn Belt, Staff Assistant, Michigan Trial Center, 1971-72

Carl F. Berger, Staff Physicist, 1966-71

Glenn D. Berkheimer, Coordinator, Michigan Trial Center, 1967-72

Joanne E. Bjerke, Secretary and Editor, 1969-75

Jane H. Bock, Staff Biologist, 1966-67

Jane A. Bowyer, Science Educator, 1971-74

Diane N. Bramwell, Administrative Assistant and Senior Editor, 1964-73

Daniel Branton, Consultant, 1965

Theodore Bredderman, Science Educator, 1965

Larry R. Bruce, Staff Assistant, Michigan Trial Center, 1968-69

Fernand Brunschwig. Artist, 1968

Sylvia A. Bunshoft, Staff Teacher, 1969-70

Peter Buri, Consultant, 1965

Anthony L. Calica, Artist, 1968-75

Kenneth Calkin, Staff Assistant, Michigan Trial Center, 1969-70

Verna J. Carlson, Staff Teacher, 1968

Zane Carothers, Consultant, 1965

Albert B. Carr, Coordinator, Hawaii Trial Center, 1966-72

Sam T. Chapman, Clerk, 1970-71

John E. Clark, Consultant, 1965

Adeline B. Collins, Secretary, 1969-72

David W. Conard, Staff Biologist, 1967-71

Deborah J. Cook, Secretary, 1970

Jenny Cook-Gumperz, Consultant, 1971

Ina Cooper, Student Assistant, 1965

Richard E. Cooper, Staff Assistant, Michigan Trial Center, 1971-72; Science Educator, 1972-74

William N. Copeland, Student Assistant, 1968

Vivian Coulter, Staff Teacher, 1970

Michael A. Crow, Student Assistant, 1968

John D. Cunningham, Staff Biologist, 1964-65

Barbara Cutler, Consultant, 1964

Nancy Cutler, Student Assistant, 1970

Catherine V. Davis, Secretary, 1968

Janie C. Davis, Secretary, 1967-68

Joseph E. Davis, Jr., Consultant and Staff Chemist, 1964-69

Stanford M. Davis, Coordinator, Los Angeles Trial Center, 1966-72

Mary Ann Debaggio, Student Assistant, 1964

Sandra F. Delesbore, Secretary, 1970-72

John W. Denzler, Artist, 1965-67

Helen Diggins, Secretary, 1975

William E. Dopkins, Clerk, 1969

Victoria Durant, Staff Teacher, 1968-69

Robert Dunk, Consultant, 1966

James R. Eakin, Coordinator and Research Assistant, 1963-75

Agnes Ehrenreich, Staff Assistant, New York Trial Center, 1966-71

Lee S. Elson, Student Assistant, 1966

Alan P. Fenech, Student Assistant and Clerk, 1968

Jack Fishleder, Consultant and Implementation Leader, 1965-75

Sandra G. Fletcher, Staff Biologist, 1964-68

Donald L. Flory, Staff Psychologist, 1968

Katherine M. Frank, Student Assistant, 1970

Marjorie Franklin, Secretary, 1974-75

Judith Friedkin, Secretary, 1965

Earl Friesen, Consultant, 1965

Melvin T. Furukawa, Artist, 1967-68

Darrel Fyffe, Staff Assistant, Michigan Trial Center, 1969-70

Coronet E. Galloway, Student Assistant, 1967-68

Wayne Gallup, Artist, 1963-64

Robert C. Gay, Student Assistant, 1966

Dorothy A. Gill, Secretary, 1967-69

Dolores M. Goff, Secretary, 1967

Sue W. Grace, Staff Biologist, 1964-66

Waldena J. Green, Secretary, 1968

Norma S. Haan, Consultant, 1967-68

Doris Hadary, Consultant, 1962-64

Elizabeth P. Hagen, Director of Evaluation, 1965-66

Ann H. Harrington, Secretary and Editor, 1966-67

Lillian Hartmann, Staff Physicist, 1965-67

Howard Heitzeg, Staff Assistant, Michigan Trial Center, 1969-70

Harvey Helfand, Artist, 1966

Sharon Herrera, Staff Teacher, 1968-70

Pamela Himsworth, Student Assistant, 1964-65

Lisa K. Hunter, Secretary, 1965-67

Victor Ichioka, Student Assistant, 1966

Willard J. Jacobson, Director of Teacher Education Development, 1965-68

Susie Jacobus, Secretary and Editor, 1973-74

Christina K. Kageyama, Staff Teacher, 1964-67

Robert Karplus, Director and Staff Physicist, 1961-75

Donald H. Kellog, Staff Assistant, Michigan Trial Center, 1969-70

Diane C. Kelly, Clerk, 1972-74

Donald Kennedy, Consultant, 1965

Michael F. Kleimo, Artist, 1969-70, 1973-75

Robert C. Knott, Staff Biologist, 1967-72

Beverly Stephen Koch, Secretary and Editor, 1965-67

T. P. Koh, Consultant, 1968-69

Allan K. Kondo, Staff Assistant, New York Trial Center, 1966-68

Seymour Kopilow, Consultant, 1965

Watson Laetsch, Consultant, 1965

Mary Ann Lanier, Staff Teacher, 1970-71

Willie E. Latimore, Student Assistant, 1967

Yvonne W. Lauber, Artist, 1966-68

Celia Stendler Lavatelli, Staff Psychologist, 1966-67

Elizabeth Lawlor, Acting Director, New York Trial Center, 1970-71

Francis X. Lawlor, Staff Assistant, New York Trial Center, 1968-71

Anton E. Lawson, Staff Assistant, Oklahoma Trial Center, 1971-72

Chester A. Lawson, Director for Life Sciences, 1965-74

Noah Lerman, Staff Physicist, 1964-66

Orley H. Lindgren, Student Assistant, 1966

Paul D. Lindquist, Staff Teacher, 1967-68

Joaquin Lira-Olivares, Artist, 1963

Thelma Hollie Lovett, Secretary, 1969-72

Vincent D. Mahoney, Research Assistant, 1968

Laurence E. Malone, Technician, 1965-72

Edmund A. Marek, Jr., Staff Assistant, Oklahoma Trial Center, 1968-70

Harry L. Marks, Artist, 1965-66

Donald E. Maxwell, Staff Assistant, Michigan Trial Center, 1969-71

David May, Staff Assistant, Michigan Trial Center, 1972-73

Barbara M. Mayer, Research Assistant, 1968

Gerald E. McClearn, Consultant, 1965

Ruth A. McKinnon, Secretary, 1966-67

Esther G. McLaughlin, Secretary, 1967-68

Richard T. McLeod, Consultant, Michigan Trial Center, 1967-69

John F. McReynolds, Research Assistant, 1965-66

El Roy L. Miller, Student Assistant, 1967

Felicia Miller, Clerk, 1975

Virginia Miltenberger, Research Assistant, 1964

Marshall A. Montgomery, Staff Physicist and Equipment Designer, 1966-75

Thomas C. Moon, Staff Assistant, Michigan Trial Center, 1969-70

George P. Moynihan, Jr., Coordinator, 1966-75

David L. Myers, Student Assistant, 1967

Christine T. Nahnsen, Secretary and Editor, 1963-64

Patricia D. Ness, Staff Psychologist, 1967-69

Harold T. Neuberger, Staff Biologist, 1966-67

Gay Nichols, Secretary and Editor, 1970-75

Tihomir Novakov, Staff Physicist, 1968

Judith Thomson Olsen, Secretary, 1968-73

Sue A. Owston, Secretary, 1968-70

Nancy McNeil Ozodi, Secretary, 1968-70

Arnold R. Pagano, Research Assistant, 1963-64

Sheryl L. Patterson, Secretary, 1966-67

Ann Penner, Secretary and Editor, 1964-65

Joyce Pershing, Secretary, 1963-64

Gordon E. Peterson, Staff Biologist, 1968-70

Rita W. Peterson, Science Educator, 1969-72

Cynthia Ann Powell, Staff Teacher, 1963

Mary Lou Prendergast, Consultant, 1965

John A. Quick, Film Specialist, 1967-73

Martin B. Rabkin, Coordinator, 1964-66

Joan Coffman Randle, Staff Teacher, 1967-74

Ronald Raven, Research Assistant, 1964

Erika Kunkel-Rawitscher, Staff Biologist, 1965-67

Betty Redsun, Research Assistant, 1964

John W. Renner, Coordinator, Oklahoma Trial Center, 1965-72

Audrey J. Richards, Staff Biologist, 1966-68

Joseph W. Riley, Staff Assistant, Michigan Trial Center, 1970-71

Mary Budd Rowe, Coordinator, New York Trial Center, 1965-71

Raymond T. Sanders, Consultant, 1965

Larry E. Schafer, Staff Assistant, Michigan Trial Center, 1969-70

Frederick B. Schmidt, Staff Assistant, Oklahoma Trial Center, 1967-69

Ida Beth Schultz, Staff Biologist, 1968-69

Frances Schwartz, Research Assistant, Teachers College, Columbia University, 1969-70

Sharon A. Scramstad, Student Assistant, 1968-69

Ruth A. Seamans, Secretary, 1967-68

Barbara Selfridge, Student Assistant, 1964-65

Jo Ann Sellers, Staff Assistant, Oklahoma Trial Center, 1970-71

Charlyn R. Sheehan, Staff Teacher, 1966-71

Ellen Y. Siegelman, Staff Psychologist, 1966-68

Gladys Sikora, Staff Assistant, New York Trial Center, 1966-68

Lorraine Silva, Staff Assistant, Hawaii Trial Center, 1967-68

Sister Ann Kathleen, Consultant, 1964

Tracy Ann Sokol, Research Assistant, 1970

Donald G. Stafford, Staff Assistant, Oklahoma Trial Center, 1967-72

Luke E. Steiner, Consultant and Staff Chemist, 1964-68

Suzanne B. Stewart, Secretary and Editor, 1967-74

Sidney Strauss, Research Assistant, 1965-67

Laurence Strong, Consultant, 1964-65

Patricia A. Summers, Staff Teacher, 1964-66

Herbert D. Thier, Assistant Director and Staff Physicist, 1962-75

Virginia C. Thompson, Consultant, 1968

Charles Tiktinsky, Student Assistant, 1967

David G. Tompkins, Staff Assistant, Michigan Trial Center, 1971-72

Olympia D. Tresmontan, Research Assistant, 1967-68

Richard F. Trump, Consultant, 1966

Lydia Uchida, Clerk, 1974-75

Laura Vacco, Student Assistant, 1965

Judith L. VanHoorn, Staff Biologist, 1965-66, 1970-71

Sherry I. Virbila, Clerk, 1969-72

Ruby A. Walker, Secretary, 1967-68

Anthony J. Walsh, Student Assistant, 1973-74

William W. Walton, Technician, 1964-68

Sylvester Webb, Science Educator, 1969-70

Eric J. Werner, Research Assistant, 1969

Susan Wernert, Student Assistant, 1965

Robert J. Whitaker, Staff Assistant, Oklahoma Trial Center, 1965-67

Walley T. Williams, Consultant, 1965

Marilyn M. Wong, Consultant, 1964-68

Hugh D. Young, Staff Physicist, 1967-68

David M. Youngdahl, Artist, 1967-70

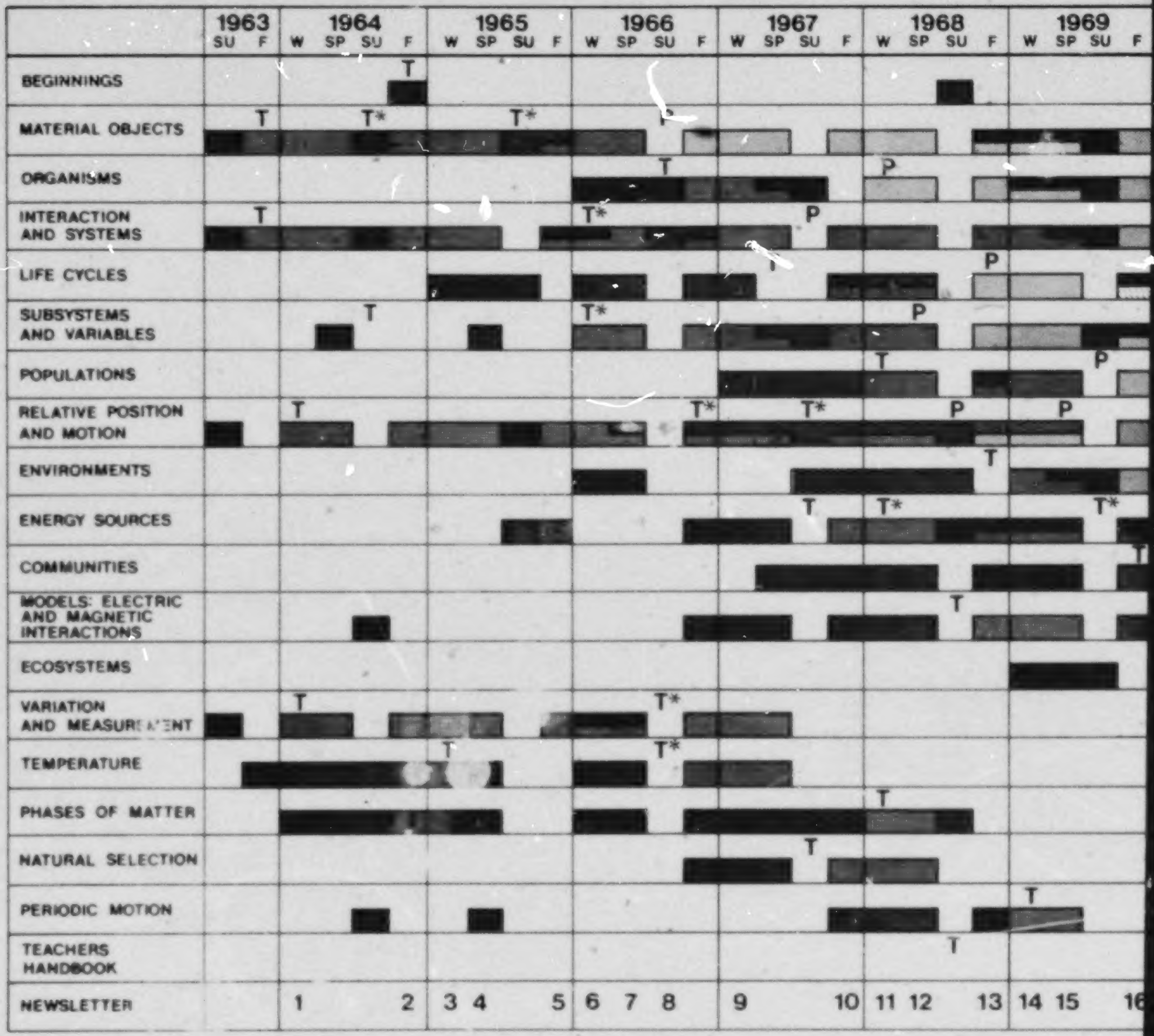
Judith A. Zacker, Secretary, 1966

Ali Zanganeh, Artist, 1963

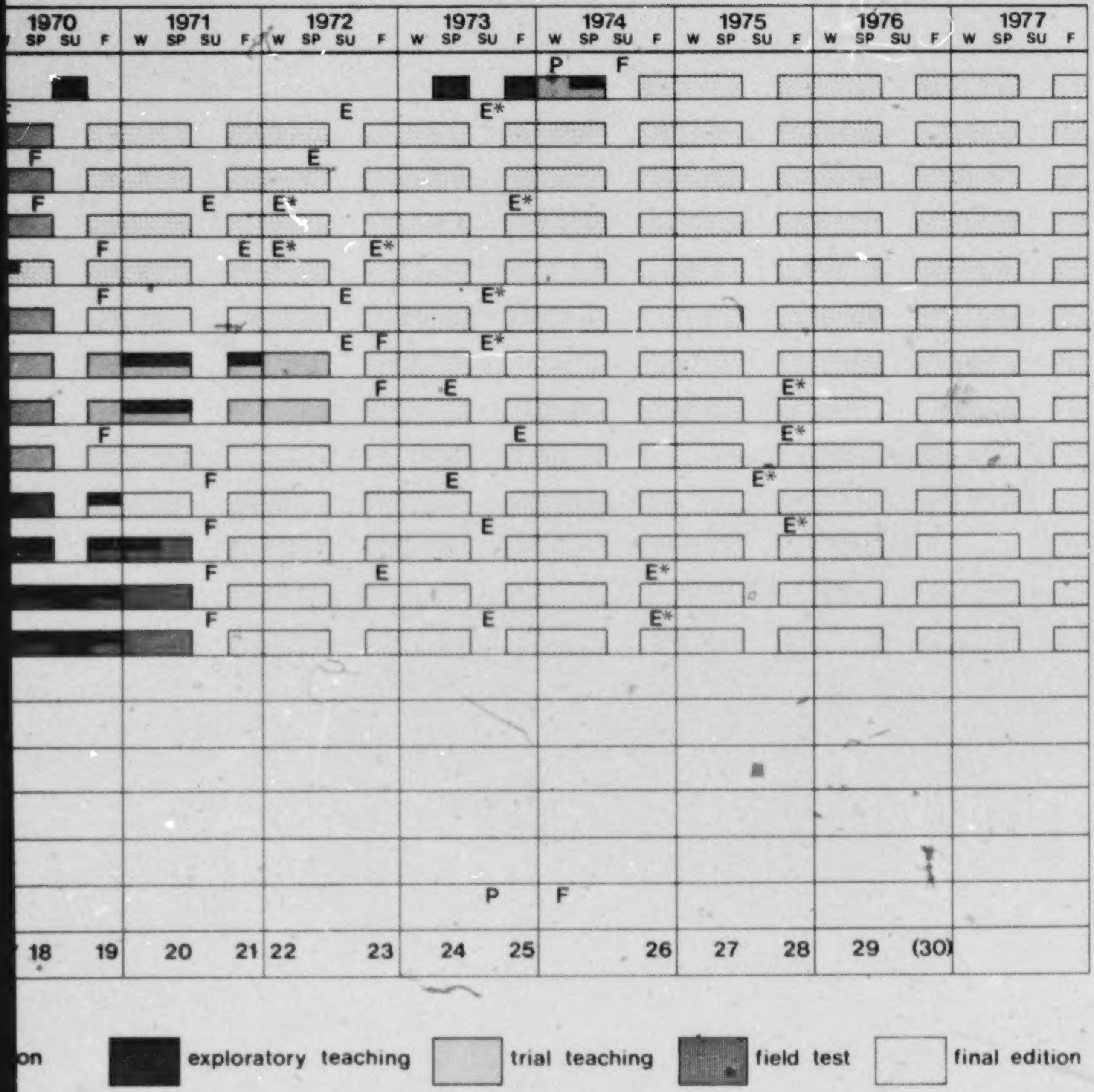
Marta Ziegenhagen, Research Assistant, 1968

Sylvia L. Zuck, Secretary, 1966-67

Appendix E SCIS Unit Publication Chart



T = trial edition P = preliminary edition F = final edition E = evaluation supplement ✱ = revised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on
exploratory teaching
trial teaching
field test
final edition

Appendix F Unit Authors

BEGINNINGS

Preliminary Edition, *Science for Kindergarten*, 1974	Sharon Herrera and Herbert D. Thier
Final Edition, 1974	Sharon Herrera and Herbert D. Thier

MATERIAL OBJECTS

Trial Edition, 1963	Herbert D. Thier and Robert Karplus
Revised Trial Edition, 1964	Herbert D. Thier
Revised Trial Edition, 1965	Jack Fishleder, Sandra Fletcher, Robert Karplus, and Herbert D. Thier
Preliminary Edition, 1966	Herbert D. Thier
Final Edition, 1970	Joan Coffman Randle and Herbert D. Thier
Evaluation Supplement	
Trial Edition, 1972	Herbert D. Thier
Revised Trial Edition, 1973	Herbert D. Thier

ORGANISMS

Trial Edition, 1966	Sandra Fletcher, Chester A. Lawson, and Erika Rawitscher-Kunkel
Preliminary Edition, 1968	Sandra Fletcher, Chester A. Lawson, and Erika Rawitscher-Kunkel
Final Edition, 1971	Sandra Fletcher, Chester A. Lawson, and Erika Rawitscher-Kunkel
Evaluation Supplement	
Trial Edition, 1972	Robert C. Knott, Chester A. Lawson, and Rita W. Peterson

INTERACTION AND SYSTEMS

Trial Edition, 1963	Robert Karplus and Herbert D. Thier
Trial Edition, *Interaction*, 1966	John Denzler, Christina Kageyama, Robert Karplus, John W. Renner, and Patricia A. Summers
Trial Edition, *Systems*, 1966	Christina Kageyama and Robert Karplus
Preliminary Edition, *Interaction*, 1967	Robert Karplus and Charlyn Sheehan
Final Edition, 1970	Robert Karplus and Joan Coffman Randle

Evaluation Supplement

Trial Edition, 1971	Robert Karplus
Revised Trial Edition, 1972	Robert Karplus
Revised Trial Edition, 1973	Robert Karplus

LIFE CYCLES

Trial Edition, 1967	Jane Bock, Sandra Fletcher, Sue Grace, Chester A. Lawson, and Sidney Strauss
Preliminary Edition, 1968	David Conard, Sandra Fletcher, and Chester A. Lawson
Final Edition, 1970	David Conard, Sandra Fletcher, and Chester A. Lawson

Evaluation Supplement

Trial Edition, 1971	Rita W. Peterson
Revised Trial Edition, 1972 (Feb.)	Rita W. Peterson
Revised Trial Edition, 1972 (Oct.)	Rita W. Peterson

SUBSYSTEMS AND VARIABLES

Trial Edition, *Solutions*, 1964	Jack Fishleder, Sue Wineland, and Robert Karplus
Trial Edition, *Subsystems*, 1966	Christina Kageyama, Robert Karplus, Patricia A. Summers, and Herbert D. Thier
Preliminary Edition, *Systems and Subsystems*, 1968	Robert Karplus, Marshall A. Montgomery, and Charlyn Sheehan
Final Edition, 1970	Carl F. Berger, Sylvia Bunshoft, Robert Karplus, and Marshall A. Montgomery

Evaluation Supplement

Trial Edition, 1972	Jane Bowyer, Robert Karplus, and Joan Coffman Randle
Revised Trial Edition, 1973	Jane Bowyer, Robert Karplus, and Joan Coffman Randle

POPULATIONS

Trial Edition, 1968	Chester A. Lawson, Paul D. Lindquist, and Audrey Richards
Revised Trial Edition, 1968	David Conard, Gordon E. Peterson, Audrey Richards, and Beth Schultz
Preliminary Edition, 1969	David Conard and Chester A. Lawson
Final Edition, 1972	David Conard, Robert C. Knott, Mary Ann Lanier, and Chester A. Lawson

Evaluation Supplement

Trial Edition, 1972	Robert C. Knott and Chester A. Lawson
Revised Trial Edition, 1973	Robert C. Knott and Chester A. Lawson

RELATIVE POSITION AND MOTION

Trial Edition, *Relativity of Position and Motion*, 1964	Robert Karplus
Revised Trial Edition, *Relativity*, 1966	Christina Kageyama and Robert Karplus
Trial Edition, *Position and Motion*, 1967	Carl F. Berger and Marshall A. Montgomery
Preliminary Edition, *Relativity*, 1968	Joan Coffman and Robert Karplus
Preliminary Edition, *Position and Motion*, 1969	Joan Coffman, Carl F. Berger, Robert Karplus, and Marshall A. Montgomery
Final Edition, 1972	Carl F. Berger, Robert Karplus, Marshall A. Montgomery, Joan Coffman Randle, and Herbert D. Thier

Evaluation Supplement

Trial Edition, 1973	Jane Bowyer and Robert Karplus
Revised Trial Edition, 1975	Jane Bowyer and Robert Karplus

ENVIRONMENTS

Trial Edition, 1968	Robert C. Knott and Chester A. Lawson
Final Edition, 1970	David Conard, Robert C. Knott, Chester A. Lawson, and Charlyn Sheehan
Evaluation Supplement	
Trial Edition, 1973	Richard E. Cooper and Chester A. Lawson
Revised Trial Edition, 1975	Richard E. Cooper and Chester A. Lawson

ENERGY SOURCES

Trial Edition, *Energy*, 1967	Joseph E. Davis, Jr., Charlyn Sheehan, and Luke E. Steiner
Trial Edition, *Approaches to Equilibrium*, 1968	Joseph E. Davis, Jr., Marshall A. Montgomery, and Herbert D. Thier
Trial Edition, 1969	Herbert D. Thier, Joan Coffman, Marshall A. Montgomery, and Suzanne Stewart
Final Edition, 1971	Carl F. Berger, Robert Karplus, Joan Coffman Randle, Herbert D. Thier, and Sylvester Webb
Evaluation Supplement	
Trial Edition, 1973	Jane Bowyer and Robert Karplus
Revised Trial Edition, 1975	Jane Bowyer and Robert Karplus

COMMUNITIES

Trial Edition, 1969	Robert C. Knott, Chester A. Lawson and Charlyn Sheehan
Final Edition, 1971	Robert C. Knott, Mary Ann Lanier, Chester A. Lawson, and Charlyn Sheehan
Evaluation Supplement	
Trial Edition, 1973	Richard E. Cooper and Chester A. Lawson
Revised Trial Edition, 1975	Richard E. Cooper and Chester A. Lawson

MODELS: ELECTRIC AND MAGNETIC INTERACTIONS

Trial Edition, 1968	Carl F. Berger, Joan Coffman, Joseph E. Davis, Jr., Barbara E. Mayer, and Hugh D. Young
Final Edition, 1971	Carl F. Berger, Sylvia Bunshoft, Robert Karplus, and Joan Coffman Randle

Evaluation Supplement

Trial Edition, 1972	Jane Bowyer, Robert Karplus, and Joan Coffman Randle
Revised Trial Edition, 1974	Jane Bowyer, Robert Karplus, and Joan Coffman Randle

ECOSYSTEMS

Trial Edition, 1970	Carl F. Berger, Robert C. Knott, Chester A. Lawson, Gordon E. Peterson, and Charlyn Sheehan
Final Edition, 1971	David Conard, Robert C. Knott, Mary Ann Lanier, Chester A. Lawson, Gordon E. Peterson, and Charlyn Sheehan

Evaluation Supplement

Trial Edition, 1973	Richard E. Cooper and Chester A. Lawson
Revised Trial Edition, 1974	Richard E. Cooper and Chester A. Lawson

Authors of units not in final edition:

VARIATION AND MEASUREMENT

Trial Edition, 1964	Herbert D. Thier and Robert Karplus
Revised Trial Edition, 1966	Noah Lerman, Charlyn Sheehan, and Herbert D. Thier

TEMPERATURE

Trial Edition, 1965	John Cunningham, Harry Marks, and Robert Karplus
Trial Edition, 1966	Joseph E. Davis, Jr., Luke E. Steiner, and Patricia A. Summers

NATURAL SELECTION

Trial Edition, 1967	Harold Neuberger

PHASES OF MATTER

Trial Edition, 1968	Joan Coffman, Joseph E. Davis, Jr., Charlyn Sheehan, and Luke E. Steiner

PERIODIC MOTION

Trial Edition, 1969	Victoria Durant and Marshall A. Montgomery

SCIS TEACHER'S HANDBOOK

Trial Edition, *SCIS Elementary Science Sourcebook*, 1968	Willard Jacobson and Allan Kondo
Preliminary Edition, 1973	Robert Karplus and Chester A. Lawson
Final Edition, 1974	Robert Karplus and Chester A. Lawson

Appendix G Motion Picture Films Produced by the SCIS Project

Teacher Education Films, Black and White

Material Objects

Experimenting With Air	15 min.	1966
Grandma's Button Box	20 min.	1965
Grouping Collection of Objects	18 min.	1965
Invention of the Concept of Material	20 min.	1965
Inventing the Comparison of Objects Using Signs	20 min.	1965
Material Objects Overview	14 min.	1967
Observing Liquids	15 min.	1965

Organisms

Children Report	7 min.	1966
I Don't Get How That Happens	28 min.	1967
Observing *Daphnia*	15 min.	1966

Interaction

Interaction Overview	11 min.	1966
Interaction Documentary	11 min.	1966
Interaction-at-a-Distance	30 min.	1962
Making Copper Chloride Solution	11 min.	1966

Systems and Subsystems

How Cold Is Ice?	10 min.	1969

Relativity

Relativity Overview	17 min.	1968
Flipbooks	12 min.	1969

Teacher Education Films, Color

Primary Grades

Don't Tell Me, I'll Find Out	22 min.	1969
How Can We Find Out?	9 min.	1968
What Would Happen If...?	24 min.	1972

Teacher Education Films, Color, continued

Upper Grades

Around the Corner	10 min.	1972
Energy and Models	20 min.	1972
Let's Try It	23 min.	1973

Classroom Films, Color

Children At Play (silent)	5 min.	1962
State of a System (sound)	10 min.	1966
Daphnia (silent)*	4 min.	1968
Frog: Tadpole to Adult (silent)*	4 min.	1968
Fun House (silent)*	4 min.	1968
Walk in Space (silent)	4 min.	1968

*Available from Rand McNally and Company.

Appendix H Dissertations Relating to SCIS

Doctoral

Leslie R. Allen. "An Examination of the Classificatory Ability of Children Who Have Been Exposed to One of the 'New' Elementary Science Programs." University of California, Berkeley, 1967.

Irvin H. Altman. "Teacher-Student Interaction in Inner-City and Advantaged Classes Using the Science Curriculum Improvement Study." University of California, Los Angeles, 1970.

Steven M. Barnes. "The Reactions of Selected Elementary Teachers to the Training for and Implementation of the Science Curriculum Improvement Study in Selected Schools in Michigan." Michigan State University, 1969.

Guilford H. Bartlett, Jr. "Relations of a Small Group Variable to Implementation of an Innovation in Elementary Science." Teachers College, Columbia University, 1971.

Carl F. Berger. "Predictions of Teaching Behaviors by Teachers of Elementary School Science." University of California, Berkeley, 1971.

Jane Bowyer. "SCIS and the Development of Scientific Literacy." University of California, Berkeley, 1975.

Talbert W. Brown. "The Influence of the Science Curriculum Improvement Study on Affective Process Development and Creative Thinking." University of Oklahoma, 1973.

Larry R. Bruce. "A Determination of the Relationships Among SCIS Teachers' Personality Traits, Attitude Toward Teacher-Pupil Relationship, Understanding of Science Process Skills and Question Types." Michigan State University, 1969.

William J. Coffia. "The Effects of an Inquiry-Centered Curriculum in Science on a Child's Achievement in Selected Academic Areas." University of Oklahoma, 1971.

Richard E. Cooper. "A Study of the Science Curriculum Improvement Study Resource Personnel Workshop Participants to Determine the Relationship Between Selected Factors and Subsequent Participant Activity." Michigan State University, 1972.

Leonard J. Garigliano. "The Relation of Wait-Time to Student Behaviors in Science Curriculum Improvement Study Lessons." Teachers College, Columbia University, 1973.

Larry M. Hovey. "Measuring Science Curriculum Improvement Study Teachers' Attitudinal Changes Toward Science." University of California, Berkeley, 1970.

Donald H. Kellogg. "An Investigation of the Effect of the Science Curriculum Improvement Study's First Year Unit, *Material Objects*, on Gains in Reading Readiness." University of Oklahoma, 1971.

Paul S. Knecht. "A Model to Facilitate the Assessment of Epistemological Quality in Elementary Science Programs." Michigan State University, 1974.

Robert C. Knott. "Hypothesis Generation, Selection of Hypotheses, and Experimental Designs by Individuals and Groups of Children in Grades 4, 6, and 8." University of California, Berkeley, 1972.

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Appendix I Formative Evaluation Reports

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4. *Material Objects Evaluation*, Spring 1966. Elizabeth Hagen, Teachers College, Columbia University.

5. *Systems, Interaction Evaluation*, Spring 1966. Patricia Ness.

6. *Relativity of Position and Motion Evaluation*, Spring 1966. Patricia Ness.

7. *Variation and Measurement Evaluation*, September 1966. Elizabeth and Robert Karplus.

8. *Systems Feedback Testing*, Fall 1966. Elizabeth Karplus and Ellen Siegelman.

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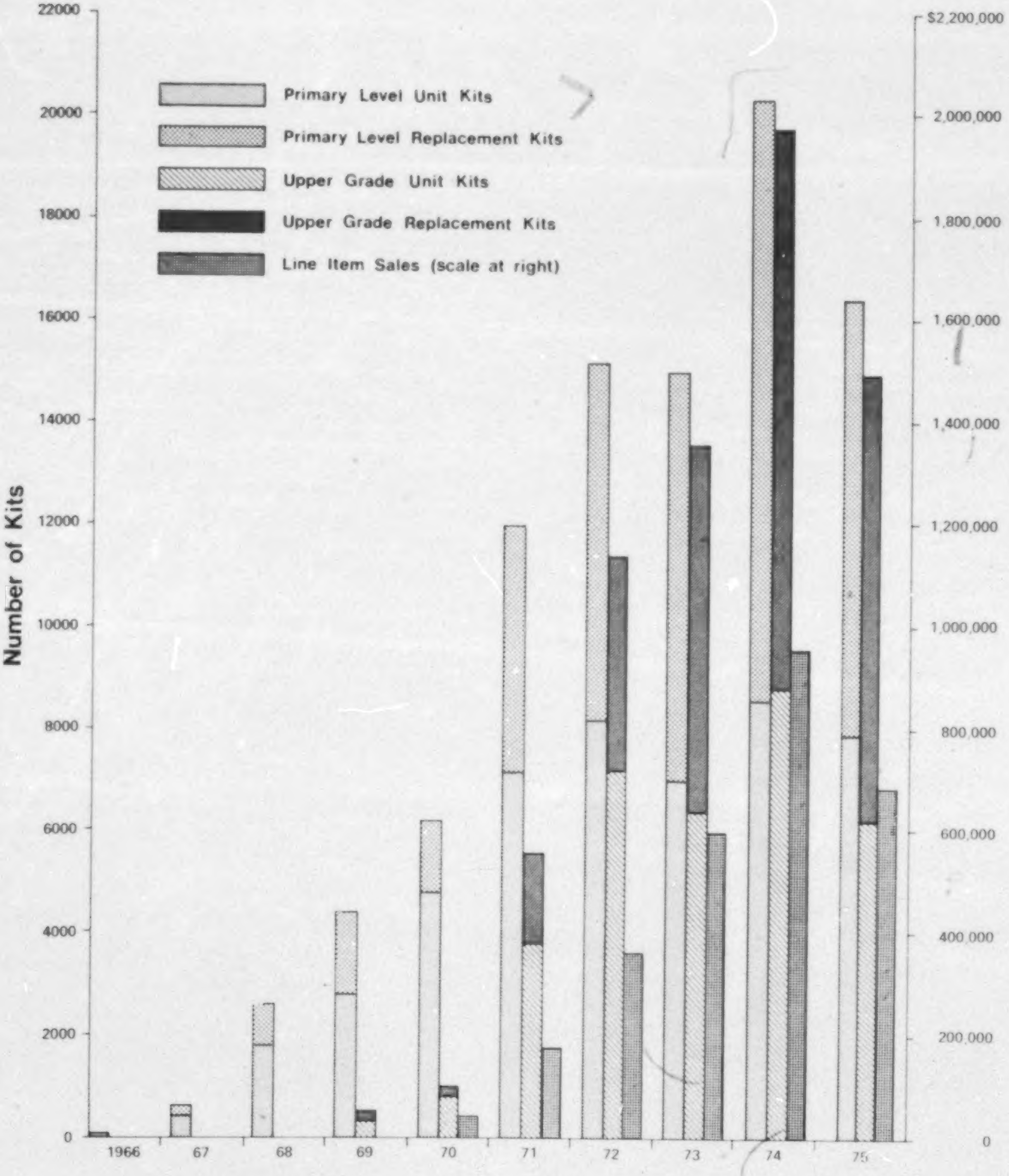
Appendix K Annual Kit and Replacement Sales



Appendix L Rand McNally SCIS Resource Centers

Arizona State University, 1973-76 Fred Staley, Director	Tempe, Arizona
California State University, 1973-76 Francis P. Collea, Director	Fullerton, California
University of Northern Colorado, 1975-76 George Crockett, Director	Greeley, Colorado
Georgia State University, 1973-76 Ashley G. Morgan, Jr., Director	Atlanta, Georgia
University of Hawaii, 1975-76 Albert Carr, Director	Honolulu, Hawaii
National College of Education, 1975-76 Helen Challand, Director	Evanston, Illinois
University of Kansas, 1974-76 William S. LaShier, Jr., Director	Lawrence, Kansas
Bridgewater State College, 1975-76 George Weygand, Director	Bridgewater, Massachusetts
Hathaway Environmental Education Institute, 1973-76 Leonard Amburgey, Director	Lincoln, Massachusetts
Westfield State College, 1975-76 Kenneth Taylor, Director	Westfield, Massachusetts
Michigan State University, 1973-75* Glenn D. Berkheimer, Director	East Lansing, Michigan
St. Cloud State College, 1974-76 John Coulter, Director	St. Cloud, Minnesota
Rutgers, The State University, 1974-76 Arthur W. Edwards, Jr., Director	New Brunswick, New Jersey
State University of New York at Stony Brook, 1974-76 Lester G. Paldy, Director	Stony Brook, New York
Miami University, 1973-76 Richard Moore, Director	Oxford, Ohio
Oregon State University, 1974-76 Karl J. Nice, Director	Corvallis, Oregon

California State College, 1974-76 Thomas C. Moon, Director	California, Pennsylvania
Temple University, 1973-74* Chester Raun, Director	Philadelphia, Pennsylvania
University of Wyoming, 1975-76 Vince Sindt, Director	Laramie, Wyoming

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*Interim support, 1971-73.